

GLASSHOUSE CROPS
RESEARCH INSTITUTE

ANNUAL REPORT
1960

RUSTINGTON
LITTLEHAMPTON . SUSSEX

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given in the World List of Scientific

Periodicals is:—

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1960

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1961

THE GLASSHOUSE CROPS RESEARCH INSTITUTE

The Glasshouse Crops Research Institute was established on the 8th September, 1953, as a company limited by guarantee, but without share capital, under the Companies Act of 1948. Its registered office is at Littlehampton, Sussex, where the main research station is being developed. The Institute succeeded the Experimental and Research Station at Cheshunt, which was in existence from 1915 to 1955, and also took over the work of the Mushroom Research Station at Yaxley, which functioned from 1946 to 1954.

In the Memorandum of Association the principal object for which the Institute has been established is stated as follows :

“To promote scientific research bearing on the cultivation of glasshouse crops and mushrooms, and of bulbs, flowers and shrubs grown in the open, and on matters ancillary thereto”.

The Institute is administered by a Governing Body consisting, at present, of fourteen members, including the Chairman, Sir William K. Slater, K.B.E. Six members are leading commercial growers who represent the section of horticultural industry served by the Institute, six are eminent scientists, and one is a Senior Education and Advisory Officer of the Ministry of Agriculture. The Governing Body is appointed by the Minister for Science and the Minister of Agriculture, Fisheries and Food.

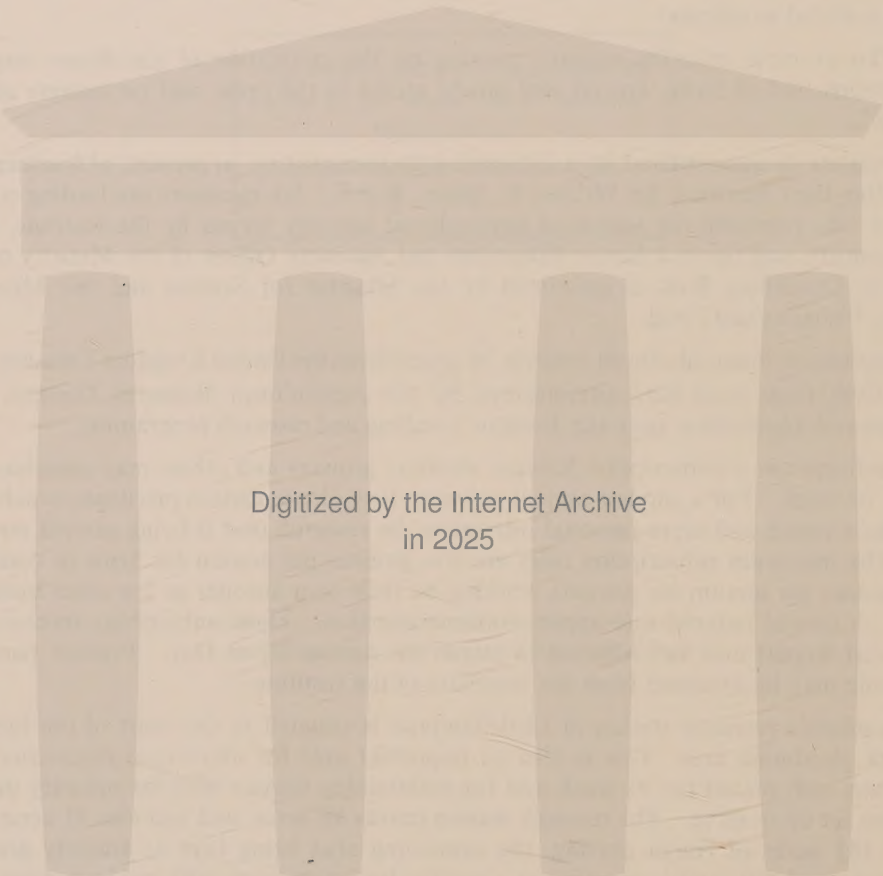
The Institute is financed almost entirely by grants from the United Kingdom Treasury. Since 1st April, 1956, these have been administered by the Agricultural Research Council, which exercises general supervision over the Institute's staffing and research programme.

The Institute has a Subscription Scheme whereby growers and others may associate themselves with its work. For a modest annual payment they obtain certain privileges which enable them to take a closer and more personal interest in the research that is being carried out at the Institute. The minimum subscription rates are five guineas per annum for firms or companies, and two guineas per annum for growers working on their own account or for other individuals interested. A special reduced rate applies to those overseas. Those subscribing receive a copy of the Annual Report and an invitation to attend the annual Open Day. Further particulars of the Scheme may be obtained from the Secretary of the Institute.

The Institute's research station at Littlehampton is situated in the heart of the important West Sussex glasshouse area. This is also an important area for mushroom production. The station is thus well placed for its work and for maintaining contact with the industry the Institute has been set up to serve. The research station covers 98 acres, and includes 41 acres arable and about 18½ acres of rough grazing, the remaining area being kept as amenity grassland. The greater part of this land is required as a reserve for future work with outdoor crops, for the supply of loam, and for re-soiling the glasshouses when experimental work requires it.

Development of the research station has reached an intermediate stage. In addition to an administration building, which also houses the library, there is a well-equipped block of laboratories with an annex for special services. There are also 1.55 acres of permanent glass for large scale experiments and trials, as well as research glasshouses for work in the fields of plant physiology, plant pathology, chemistry and crop protection. A special unit, including three growing houses, for work on mushrooms completes the research facilities, which are supported by a wide range of ancillary buildings, such as boiler houses, potting sheds, stores, etc. Other research facilities are being planned.

The scientific and experimental staff of the Institute at present numbers 37, most of whom are honours graduates.



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GLASSHOUSE CROPS RESEARCH INSTITUTE

GOVERNING BODY

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Vice-Chairman

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Professor N. A. BURGESS, M.Sc., Ph.D. (*from 22.12.60*)
Professor F. G. GREGORY, D.Sc., F.R.S.
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Professor R. L. WAIN, D.Sc., Ph.D., F.R.I.C., F.R.S.
Professor W. T. WILLIAMS, A.R.C.S., D.I.C., D.Sc., Ph.D., F.L.S. (*from 4.2.60*)

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Auditors

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Director

F. W. TOOVEY, O.B.E., B.Sc.(Lond.), A.R.C.S., A.I.C.T.A., M.I.BIOL.

SCIENTIFIC STAFF

Plant Breeding

L. A. DARBY, B.Sc.(Wales)

A. C. HASTIE, B.Sc. (Glasgow) (*from 1.10.60*)

J. W. M. SMITH

Assistant (Scientific)

Miss P. R. AINSLEY

Plant Physiology

E. R. LEONARD, D.Sc. (Lond.), A.R.C.S., M.I.BIOL.,

H. R. B. HACK, B.A. (Cantab.)

Assistants (Scientific)

R. BROWN, Z. J. KULWIEC, Mrs. P. CORNISH (*née* CLARK), Miss C. JONES

Chemistry

G. W. WINSOR, B.Sc. (Bristol), Ph.D. (Lond.), D.I.C., A.R.I.C.

J. N. DAVIES, B.Sc., Ph.D. (Lond.)

J. H. L. MESSING, B.Sc. (Wales)

D. M. MASSEY, B.Sc. (Bristol)

M. I. E. LONG

G. E. HOBSON, B.Sc. (Nottingham), M.Sc. (Lond.)

Assistants (Scientific)

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Miss M. COLEMAN, Miss D. SIBLEY (*until 13.5.60*), Miss L. HUGHES (*from 23.5.60*
to 3.12.60), Miss B. MARSHALL (*from 30.5.60*), K. V. AYLING (*from 25.7.60*),
Miss R. BOWERMAN (*from 1.10.60*), Miss L. NASH (*from 5.12.60*)

Statistics

D. COOKE, M.A., DIP.STAT. (Oxon.)

Assistant (Scientific)

Miss E. J. WINGATE

Plant Pathology Division

L. BROADBENT, D.Sc. (Lond.), Ph.D., M.I.BIOL.

Entomology

N. W. HUSSEY, B.Sc.(Wales), Ph.D.(Edin.)

W. J. PARR, M.I.BIOL.

I. J. WYATT, B.Sc. (Lond.), DIP.AGRIC.SCI. (Cantab.), DIP.TROP.SCI. (Trinidad),

Miss B. GURNEY

Assistant (Scientific)

R. I. MITCHELL

Mycology

P. H. WILLIAMS, B.Sc. (Lond.), M.I.BIOL.

Miss M. H. EBBEN, M.A. (Cantab.), M.I.BIOL.

Miss D. G. GANDY, M.Sc. (Lond.)

Assistants (Scientific)

Miss P. SHOESMITH, Miss J. KERNER

Nematology

J. J. HESLING, B.Sc. (Lond.), A.R.C.S. (*from 1.12.60*)

Virology

M. HOLLINGS, B.Sc. (Nottingham), M.I.BIOL.

R. HOWLES, B.A., Ph.D. (Cantab.)

Miss O. M. STONE, M.A., Ph.D. (Cantab.), M.I.BIOL.

Miss M. E. NORRISH, B.A. (*from 14.3.60*)

Assistants (Scientific)

R. PAWLEY, P. WEATHERDON

Crop Protection

W. H. READ, M.Sc. (Birmingham), F.R.I.C.

R. J. SMITH, B.Sc., Ph.D. (Lond.)

J. T. HUGHES, B.Sc. (Lond.), A.R.I.C.

Mrs. V. A. COOKE, B.Sc. (Hull)

Miss P. M. Smith, B.Sc. (Lond.)

Assistants (Scientific)

Miss J. MARTIN, Miss B. HOTSTON, Miss B. FINCH

Horticulture

G. F. SHEARD, M.Sc. (Leeds)

A. J. COOPER, B.Sc. (Lond.), Ph.D. (Reading)

P. B. FLEGG, B.Sc. (Reading), A.R.I.C., M.I.BIOL.

A. C. BUNT, N.D.H.

Assistants (Scientific)

Mrs. B. COOPER (*until 31.8.60*), Miss I. I. WARMAN, Miss N. PESCOTT (*from 5.12.60*)

Technical Services & Maintenance Unit

J. E. MORTON, A.R.P.S., F.R.M.S., M.I.Biol.

Assistant (Scientific)

Miss G. MARSH

Instrument Technician

R. E. RANDALL (from 21.11.60)

Maintenance Staff

W. M. TOMLINSON (from 12.9.60), R. FROST, R. MINGAY, G. CARRE, B. ROCKALL

Scientific Liaison Officer

G. F. SHEARD, M.Sc.

(also Head of the Horticulture Department)

ADMINISTRATION

Secretary

J. BISHOP, A.C.I.S.

Accounts Officer

D. M. HART, A.C.I.S.

Director's Secretary

Mrs. E. J. BESWICK

Clerical Staff

Miss R. GURTEEN (until 30.9.60), Miss M. M. K. BALDWIN, Miss R. M. JONES,

Miss J. MCCARTHY, Miss M. M. DUNSTER (from 5.10.60)

Librarian

Miss G. DUNSTER, B.A. (Lond.)

NURSERY STAFF

Nursery Manager and Demonstrator

J. M. EVANS, N.D.H.

Foreman

L. TOMS (from 29.1.60)

Assistants (with more than five years' service at 31.12.60)

F. BLAKE (32 years), P. DAWES, Miss R. MILLS, Mrs. J. HOTHER, S. BARNETT

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I. INTRODUCTION

The Institute was established in September, 1953, so this report covers the seventh year of its existence. At the 1960 Open Day the Chairman spoke of "seven lean years"—referring to the many difficulties encountered in the period—but it is hoped that the report that follows will show that we have emerged into a period "yielding rich returns", which is the dictionary definition of fat, the opposite of lean.

The year has in fact been notable for the progress made in tomato breeding, culminating in the distribution of the new compact-habit varieties which have been received with so much interest by growers the length and breadth of the country. This is perhaps the most tangible result of our research to date, but nothing should belittle the steady accumulation of knowledge from the work of other Departments, which is undoubtedly having its impact on the scientific development of the industry. The research programme as a whole has gathered great impetus, and a wealth of information of practical value, immediate or potential, is being obtained.

Governing Body

We were very sorry to have to take leave of our Chairman, Mr. T. Ainslie Robertson, whose retirement on 29th September, 1960, was compelled under the age limit. Mr. Robertson was the first Chairman of the Governing Body, and during his period of office the Institute made great strides, despite many difficulties, and can now claim a worthy place among the national research establishments. The successful development of the Institute during its early years owes much to Mr. Robertson's wise guidance and sense of purpose, and it is sad that he did not live long after his retirement to see the further development in which he would surely have taken great pride. Mr. Robertson died on 23rd November, and our sincere sympathies go to his family in their sad loss. A memorial service was held at the Queen's Chapel of the Savoy on 14th December. We were happy that at the last Governing Body meeting he attended Mr. Robertson was able to plant a small group of ornamental trees in front of the new administration block to commemorate his term of office as first Chairman of the Governing Body.

Sir William Slater, K.B.E., was appointed to succeed Mr. Robertson, his date of appointment being 1st October, 1960. As the former Secretary to the Agricultural Research Council Sir William is no stranger to the Institute, and we were delighted to welcome him as our new Chairman.

We were also pleased to welcome Professor W. T. Williams, who holds the Chair of Botany at the University of Southampton, as a new member of the Governing Body, his appointment dating from 4th February. Mr. E. J. Mount relinquished his appointment midway through the year because of the pressure of his other commitments. Mr. D. G. Frampton, the well-known Sussex grower, was appointed to succeed him, although we did not receive news of this until after the end of the year. At the same time we were also pleased to learn that Professor N. A. Burges, of the Hartley Botanical Laboratories, Liverpool, had accepted an invitation to fill the remaining vacancy on the Governing Body, his appointment dating from 22nd December, 1960.

Our warmest congratulations go to two members of the Governing Body for honours bestowed on them during the year. Sir Gerard Thornton received his Knighthood in the Birthday Honours List—fitting recognition of his outstanding scientific career, mostly at Rothamsted, and of his services as Foreign Secretary of the Royal Society from 1955 to 1960. Professor R. L. Wain, Professor of Agricultural Chemistry in the University of London (Wye College) and distinguished for his researches in plant auxins and systemic herbicides, was elected a Fellow of the Royal Society.

The Governing Body has found it desirable to meet more frequently, and five ordinary meetings (one an adjourned meeting) were held during the course of the year. The Sixth Annual General Meeting was held on 1st March, 1960, when the Chairman's Report and the Accounts and Balance Sheet for the year ended 30th September, 1959, were approved and adopted.

The General Purposes Committee met twice, and dealt with certain other business by correspondence. The Staff and Research Committee held no formal meeting, but a quorum of the Committee was convened on two occasions to interview candidates for appointment to the scientific staff.

A meeting of the Heating Sub-Committee was held at the Institute on 29th February to discuss the final specifications for the new heating system and related matters.

Staff and students

The scientific staff was expanded still further by the appointment of an additional Plant Breeder, Mr. A. C. Hastie, B.Sc.(Glasgow), on 1st October, and a Nematologist, Mr. J. J. Hesling, B.Sc.(Lond.), A.R.C.S., on 1st December.

An Assistant Experimental Officer (Miss M. E. Norrish) was added to the staff of the Virology Department.

Two other important new posts were those of Maintenance Engineer and Instrument Technician, Mr. W. M. Tomlinson being appointed to the former on 12th September, and Mr. R. E. Randall to the latter on 21st November. The Maintenance Engineer has as his first task the installation of the distribution system for the new heating scheme for the trial glasshouses. The Instrument Technician's duties include not only the maintenance and servicing of scientific equipment, but also the selection and development of suitable instruments for the various physical measurements that have to be made in the course of the Institute's work.

Dr. A. J. Cooper and Mr. P. B. Flegg were transferred to the Horticulture Department in accordance with the recommendations of the Visiting Group.

There were several changes in the staff of Assistants (Scientific) which are shown in the staff list published at the beginning of this report.

Miss R. Gurteen, Clerical Assistant in the accounts office, retired at the end of September. She had worked at the Institute since 1955, having been appointed shortly after the headquarters office was opened at Littlehampton. Miss M. M. Dunster was appointed to replace her.

During the summer we were again glad to employ a number of students for short periods to assist with the recording of the glasshouse experiments and for other duties. This not only helps us with our work but also gives the students an insight into scientific research which may be valuable to them later on.

We were also pleased to meet a request from the Brunel College of Technology, Acton, to employ a Diploma student (A. J. Redfern), who was taking a sandwich course in applied biology, on the nursery for six months as part of the industrial training required by the course.

Another student (R. W. Polley) is doing his year's practical training at the Institute before taking a degree course in horticulture at the University of Nottingham, Sutton Bonington. He started work on 5th September.

The post of Nursery Foreman, left vacant when Tom Syer resigned last year, was filled by the promotion of Len Toms from the nursery staff.

Capital developments

There was rather a lull in capital developments, but much time was spent in planning facilities still required. This applied particularly to the special purpose research glasshouse and laboratory unit for the Plant Pathology Division. This scheme has received the most thorough examination, not only with a view to keeping its cost to the minimum but also to ensure that it will provide exactly the conditions required. We have received every assistance in this from Mr. L. G. Morris, of the National Institute of Agricultural Engineering, and Mr. John Musgrove, of the Nuffield Foundation Division for Architectural Studies, and we very much appreciate the immense amount of time they have given to studying our requirements. By the end of the year the design plans had reached their final form, and with the help of the engineering firms consulted a provisional estimate of the cost of the project had been arrived at. The Treasury were then approached for authority to invite tenders on this basis.

It will be another year, at least, before this big scheme can be completed, and it is therefore perhaps worth mentioning that it will provide facilities for virus, entomological and nematological work in one unit comprising a compartmented and screened glasshouse (in two sections), with attached laboratories, potting shed and constant temperature rooms. The screening of the glasshouse compartments presents special problems, and a forced draught ventilation system is to be installed; in addition to its cooling function the positive pressure it will give in the glasshouse should help to exclude insects or confine them to the compartment in which they are being studied or used.

The administration building was completed early in the year, and when the administrative staff and the library had been moved into it the necessary alterations to the vacated rooms in the laboratory block were carried out under a separate contract. The extension to the laboratory annexe and the covered way connecting the administration building to the laboratories were also completed.

The final outline specifications for modifying the heating system in the trial glasshouses were endorsed by the Governing Body's Heating Sub-Committee, and a Treasury grant for the scheme was received about the middle of the year. It was decided that the Institute's architects should be responsible for the heat production unit, comprising the boiler house, boilers and ancillary equipment and the oil storage tanks, while the heat distribution system will be installed by the Institute's staff. Tenders for the building, heating and electrical contracts for the heat production unit were invited in September, and work on the scheme was in progress during the last quarter of the year. A start was also made on the distribution mains. Although at one time it was hoped to have the new system installed in time for the 1961 season this proved impossible, and the intention now is to complete the work before the autumn of that year, as soon as the crops can be cleared from the houses and in time for propagation for the 1962 season.

Subscription Scheme

There has been little change in support for the Subscription Scheme, the numbers participating at the end of the year being as follows :

Companies or firms	75
Individuals	104
Overseas subscribers	6
	185

We owe a debt of gratitude to this small band of growers and others who show their interest in our work in this way. Their support is a great encouragement to us, and their subscriptions, after meeting the cost of privileges to which they are entitled, provide a small fund which can be used to further the work of the Institute in various desirable ways which could not otherwise be paid for out of public funds.

Miscellaneous

Staff social activities

The annual Christmas party arranged by the Staff Association was again a great success, and the enjoyment of the occasion was much enhanced because it was possible to hold it in the new Conference Room for the first time. Earlier, on 5th November, the usual fireworks party, specially for the children, was held. The Horticultural Society continues to be active, and the annual summer show in August attracted a record entry.

Liaison

The Director accepted an invitation to serve on the Horticulture Committee of the Agricultural Improvement Council. Mr. Read, Head of the Crop Protection Department, has become a member of the Scientific Advisory Committee set up under the Agricultural Chemicals Approval Scheme. Miss Gandy has been appointed Honorary Secretary of the International Commission on Mushroom Science. Dr. Hussey was elected to the Council of the Association of Applied Biologists. Liaison with other official bodies and experimental stations continued as in the past, and we must again mention the very friendly relations that exist with the National Agricultural Advisory Service which is so helpful to us in enabling us to keep in touch with the industry's problems and in making the Institute's work known to growers.

Open Day

The annual Open Day was brought forward to May 17th, and despite the earlier date the weather was again very kind. It was perhaps the most successful of these occasions held so far, 156 subscribers and guests, who had been specially invited, sitting down to lunch. During the afternoon, when a programme of set demonstrations was arranged, we kept open house, and it was made known that any growers and others genuinely interested in the research programme were welcome to attend. It was estimated that the total number of visitors was about 420. A preview for the press was held on 6th May, ten journals and papers being represented.

Exhibitions and Shows

An exhibit illustrating the Institute's breeding work on tomatoes was staged at the Sussex County Show at Horsham on 15th-16th June. The exhibit was awarded a Silver Medal, and great credit is due to Mr. Darby who arranged it with the assistance of the Technical Services Unit under Mr. Morton. The medal proved a fiction, but we shall have a permanent memento of this success as with the proceeds of the money prize a hand-carved Chairman's gavel, suitably engraved, was obtained for use at Governing Body meetings.

Conferences

The scientific staff continue to play a full part in the many technical conferences bearing on their work held in various parts of the country and overseas, and the list of conferences attended, which follows, was longer than ever. Specially noteworthy was the 11th International Congress of Entomology in Vienna from 16th to 26th August, attended by Dr. N. W. Hussey.

<i>Date</i>	<i>Place</i>	<i>Subject or Title of Conference</i>	<i>Staff attending</i>
January 2nd	Plumpton	Glasshouse management	G. F. Sheard
January 4th	Oaklands	Eastern Regional Growers' Conference	G. F. Sheard and Dr. L. Broadbent
January 6-8th	Pershire	N.A.A.S. Horticultural Officers' Refresher Course	M. Hollings and Dr. G. W. Winsor
January 19th	Starcross	Conference on insecticidal control of potato virus spread	Dr. L. Broadbent
January 28th	Babbacombe	N.A.A.S. S.W. Region Horticultural Officers' Refresher Course	G. F. Sheard
February 12th	London	Association of British Manufacturers of Agricultural Chemicals	W. H. Read, Dr. N. W. Hussey and J. T. Hughes
February 19th	Oaklands	Eastern Regional Growers' Conference on chrysanthemums	M. Hollings
February 23rd	Reading	E.R.A. conference on methods of measuring soil moisture	G. F. Sheard and H. Hack
March 1-2nd	Rosewarne	3rd N.A.A.S. Bulbs Conference	Dr. G. W. Winsor and Miss P. M. Smith
March 15th	London	Discussion on keeping quality of roses arranged by British Flower Industry Association.	G. F. Sheard
March 30th - April 1st	East Malling	A.R.C. Conference of Research Workers on Insecticides, Fungicides and Herbicides	J. T. Hughes and Miss P. M. Smith
April 12th	N. Ireland	Glasshouse Conference	G. F. Sheard
April 20-22nd	London	Symposium on analysis of soils, plants and fertilizers (Agriculture Group of Society of Chemical Industry, Fertilizer Society and Society for Analytical Chemistry)	Dr. G. W. Winsor, M. I. E. Long and D. M. Massey
May 27th	London	A.R.C. Conference of Directors of Agricultural Research Institutes	F. W. Toovey
June 17th	Cambridge	Conference on Pest Control (East Anglian Regional Advisory Council for Further Education)	W. H. Read
July 1st	Dublin	National Farm Machinery Research Conference	G. F. Sheard
July 6-15th	London	7th Commonwealth Entomological Conference	Dr. L. Broadbent and I. J. Wyatt
July 15-22nd	London	6th Commonwealth Mycological Conference	F. W. Toovey, Dr. O. M. Stone and Miss M. H. Ebben
August 16-26th	Vienna	XIth International Congress of Entomology	Dr. N. W. Hussey
Sept. 15-18th	Oaklands	Horticultural Refresher Course	G. F. Sheard
Sept. 16-18th	Durham	Modern statistical techniques (Royal Statistical Society)	D. Cooke
October 5th	Exeter	N.A.A.S. conference on problems of anemone growers	W. H. Read and M. Hollings

Oct. 10th-12th	Weston-super-Mare	Mushroom Industry Conference (organized by the Mushroom Growers' Association)	Dr. N. W. Hussey, D. Cooke, P. B. Flegg and I. J. Wyatt
November 8th	Preston	N.A.A.S. Glasshouse Conference	G. F. Sheard
November 10th	Sunningdale	N.A.A.S. South Eastern Regional Horticultural Officers' Refresher Course	M. Hollings and A. C. Bunt
December 13th	Cambridge	N.I.A.B. Crop Conference (in connection with F.A.O. World Seeds Year Campaign)	F. W. Toovey

Talks, lectures, papers by staff

The work of the Institute was made known in many talks and lectures given by members of the staff, and in papers delivered at some of the conferences mentioned above. The full list was as follows:

January 2nd	G. F. Sheard	"Recent developments in soil sterilisation by heat and chemicals" (at the conference on glasshouse management at Plumpton)
January 4th	G. F. Sheard Dr. L. Broadbent	"Tomatoes—preplanting preparations", "Tomato nutrition", and "Virus diseases of tomato" (at the Eastern Regional Growers' conference at Oaklands)
January 6-8th	M. Hollings Dr. G. W. Winsor	"Virus control in chrysanthemums and carnations", and "Tomato nutrition" (at the N.A.A.S. Horticultural Officers' Refresher Course at Pershore)
January 7th	G. F. Sheard	"The work of the G.C.R.I." (to the Ferring Horticultural Society)
January 11th	G. F. Sheard	"The glasshouse industry in relation to West Sussex" (at a W. Sussex Constabulary Sergeants' Training Course)
January 20th	Dr. L. Broadbent	"Insecticides and potato seed production" (to N.A.A.S. and N.F.U. at Camborne, Cornwall)
January 24th	G. F. Sheard	Discussion on tomatoes (in the B.B.C. Scottish Growers' programme)
January 28th	G. F. Sheard	"Horticultural machinery for use in glasshouses" (at the N.A.A.S. Horticultural Officers' Refresher Course at Babbacombe)
February 12th	Dr. A. J. Cooper	"Growth trends in the tomato plant" (to the Association of Applied Biologists in London)
February 19th	M. Hollings	"Virus diseases of chrysanthemums and their control" (at the Growers' Conference at Oaklands)
March 8th	G. F. Sheard	"Research into factors affecting tomato quality" (at the Kent Horticultural Institute, Swanley)
March 18th	Dr. L. Broadbent	"The spread and control of plant viruses" (to the staff of the Long Ashton Research Station)
March 25th	G. F. Sheard	"Tomato quality" (to the Surrey Horticultural Progress Club, Guildford)
April 12th	G. F. Sheard	"Aids to more efficient glasshouse production" (at the Glasshouse Conference in N. Ireland)

April 28th	F. W. Toovey	"Scope and present work of the G.C.R.I." (at a growers' meeting in Guernsey organized by the Guernsey Education Council)
June 17th	W. H. Read	"Insect pests of glasshouse crops" (at the Conference on Pest Control in Cambridge)
July 1st	G. F. Sheard	"Mechanisation in horticulture" (at the National Farm Machinery Conference in Dublin)
July 14th	Dr. L. Broadbent	"Control by insecticides of the spread of plant viruses" (at a joint meeting of the Commonwealth Entomological and Mycological Conferences in London)
August 21st	Dr. G. W. Winsor	Talk on the chemistry of tomato flavour (in the Southern Television programme on "Taste" in the "Farm in the South" series)
September 15th	G. F. Sheard	"The changing pattern" (at the Horticultural Refresher Course at Oaklands)
October 10-12th	D. Cooke & P. B. Flegg Dr. N. W. Hussey & I. J. Wyatt	"Harvesting practices", and "Some economic considerations in the control of mushroom pests" (at the Mushroom Industry Conference at Weston-super-Mare)
October 11th	G. F. Sheard	"Recent work at G.C.R.I. of interest to Lancashire" (to the Blackpool N.F.U. Specialist Glasshouse Branch)
October 26th	G. F. Sheard	"The work of the G.C.R.I." (to the Derby Horticultural Discussion Society)
November 1st	L. A. Darby	"Tomato varieties" (at a N.A.A.S. growers' meeting in Worthing)
November 8th	G. F. Sheard	"Future prospects in the glasshouse industry" (at the N.A.A.S. Glasshouse Conference in Preston)
November 10th	A. C. Bunt M. Hollings	"Loamless composts", and "Heat therapy of chrysanthemums for the elimination of viruses" (at the N.A.A.S. Horticultural Officers' Refresher Course at Sunningdale)
November 10th	L. A. Darby	"The search for new varieties" (to the Somerset Glasshouse Growers' Club in Taunton)
November 15th	G. F. Sheard	"Tomato growing" (to the Jersey Growers' Association)
November 30th	Dr. L. Broadbent	"Control of potato and Brassica viruses" (to representatives and staff of Haywood Chemicals Ltd., at Swanley, Kent)
December 9th	Dr. O. M. Stone	"Alternate host plants of cucumber powdery mildew" (to the Association of Applied Biologists in London)
December 16th	Dr. L. Broadbent	"Recent work on potato and tomato virus diseases" (to the Surrey Horticultural Progress Club at Guildford)

In addition to the above Mr. Darby was a member of a "Brains Trust" on tomato fruit quality in Worthing on February 19th, and Dr. Hussey took part in a similar mental exercise at the Mushroom Industry Conference at Weston-super-Mare in October.

Overseas visits

The A.R.C. again made special travel grants available to enable members of the staff to make overseas visits in the interests of their work. Such visits are undoubtedly of the greatest value in keeping the Institute informed of developments in other countries.

Mr. L. A. Darby visited Holland from 29th May to 4th June to study work in progress at a number of research establishments and for discussions with commercial organisations involved in breeding glasshouse crops.

Dr. N. W. Hussey attended the 11th International Congress of Entomology in Vienna in August, as already mentioned.

Mr. Hollings undertook a lengthy visit to the United States, extending over four months from the end of March. The main purpose of the visit was to obtain first-hand experience of yellows-type viruses, which seem likely to become important in this country, by spending two months at the University of California, Berkeley, with Dr. C. E. Yarwood, the expert in this field. On his return across the States Mr. Hollings discussed specific problems with virus workers at various centres in other parts of the country and made a special study of the techniques in use.

Other visits

Mr. Sheard went to Dublin on 31st March to advise on the layout of glasshouses at the new horticultural station which is being developed by the Agricultural Institute. His experience of these matters was again in demand later in the year when he visited Guernsey, in September, to advise the States Horticultural Advisory Service Committee on the selection of a site for an experiment station. Mr. Darby also visited Guernsey, in July, to inspect the performance of his tomato selections. Dr. Broadbent visited Cornwall and the Isles of Scilly in January to study bulb problems.

There were of course many other visits paid to research centres and growers' holdings in the interests of the Institute's work, contacts which are nearly always very well worth while.

Visitors

The number of visitors to the Institute shows no sign of decreasing—rather the opposite, in fact—and while this is a cause of pride and satisfaction it does undoubtedly impose a considerable burden on the staff. However, philosophically, we take the view that not only is it a necessary part of our duties in making our work known and in ensuring the exchange of scientific information, but it is also often of value in unexpected ways.

An unusually large number of organised parties was received. The Sixth Commonwealth Mycological Conference honoured us with a visit in July, and the Agriculture Group of the Society of Chemical Industry made the Institute the venue for their annual summer outing in June.

Another group of N.A.A.S. Horticultural Officers came in May as part of their regular programme of visits to research stations. The N.A.A.S. Advisory Soil Chemists came in June, and later, in September, the Plant Health Inspectors of the Ministry of Agriculture visited the Institute for instruction in the virus diseases of ornamentals by Mr. Hollings.

On 8th September a large party of journalists, mostly women, was received at the request of the Tomato and Cucumber Marketing Board. They came particularly to discuss the question of flavour in tomato fruit, and were addressed by members of the staff with an interest in this subject. The proceedings included a short tour of the nursery to enable the visitors to see something of the way in which tomatoes are grown under glass, and at the end of the afternoon the visitors were invited to take part in a tasting test arranged by the staff.

The full list of visiting parties, with the approximate number in the party where known, was as follows :

March 14th	Laboratorium I.W.O.N.L., Rijkstuinbouwschool, Vilvoorde, Belgium
March 17th	West Sussex Flowers Working Party (9)
April 27th	Staff and students, Kent Farm and Horticultural Institute
May 3rd	Littlehampton Rotary Club
May 11th	N.A.A.S. Horticultural Officers (65)
May 18th	N.A.A.S. Glasshouse Group (8)
June 15th	Sussex Centre of Institute of British Photographers
June 22nd	N.A.A.S. Advisory Soil Chemists (40)
June 24th	Agriculture Group, Society of Chemical Industry (30)
June 27th	Prudential Assurance Company, Brighton, Staff Horticultural Society (15)
June 28th	Horticultural Advisory Officers, Holland
July 4th	Boys from Blessed Philip Howard School, Barnham (36)
July 6th	Students from Portsmouth Training College (12)
July 18th	Students from Waterperry Horticultural School
July 26th	6th Commonwealth Mycological Conference
August 12th	Overseas students (Holland, Austria and Germany)
August 15th	Brighton and Hove 41 Club (30)
September 7th	Bognor Regis Natural History Society
September 8th	Journalists (at request of Tomato and Cucumber Marketing Board)
September 15th	Plant Health Inspectors, Ministry of Agriculture (24)
October 4th	Reading University horticulture students (30)
November 9th	Masters and boys of Shoreham Grammar School (20)
November 11th	Lecturer and students of Bognor Regis Training College (12)
December 15th	West Sussex Flowers Working Party (8)

The considerable number of visitors we continue to receive from overseas is gratifying evidence of the Institute's international standing. Among those we were particularly glad to welcome was Dr. R. Fritzsche, Director-Designate of the Wädenswil horticultural station in Switzerland, and Dr. "Bob" Holley, of the Colorado State University, U.S.A., whose name is a household word among carnation growers the world over. Professor Daskaloff, Deputy President of the Bulgarian Academy of Sciences, also honoured us with a visit.

The full list of overseas visitors was as follows :

<i>Australia :</i>	Dr. J. H. Palmer, Irrigation Research Station, C.S.I.R.O., Griffith.
<i>Belgium :</i>	Ir. H. Degry.
<i>Bulgaria :</i>	Professor Christo Daskaloff, Deputy President, Bulgarian Academy of Sciences.
<i>Canada :</i>	Dr. C. H. Goulden, Assistant Deputy Minister (Research), Department of Agriculture. Mr. A. P. Arnason, Department of Agriculture. Dr. N. D. Holmes, Department of Agriculture.
<i>Denmark :</i>	Mr. V. Aa Hallig, Statens Vaeksthusforsog Mr. E. Jensen, Danish Growers' Association.
<i>Eire :</i>	Mr. M. Woods, Agricultural Institute, Dublin. Mr. F. M. O'Carroll, Statistician, Agricultural Institute, Dublin.
<i>Finland :</i>	Miss Kirsti Osara, Department of Horticulture, Agricultural Research Centre.
<i>Germany :</i>	Dr. G. Crüger, Cologne.
<i>Holland :</i>	Mr. C. J. van der Post, Institute for Land and Water Management Research. Dr. K. Verhoeff, Phytopathologist, Horticulture Experiment Station, Naaldwijk. Mr. S. K. P. Groot, seed grower.
<i>Iceland :</i>	Messrs. B. & L. Helgason, and H. Herbutsdohlin, Reykjavik.
<i>India :</i>	Professor K. S. Bhargava, Pathologist. Mr. Albuquerque, Superintendent of Cashew Nut Research Station, Mysore. Mr. Moyiyuddin, Areca Nut Station, Mysore. Dr. N. B. Kulkarni, Sugar-cane Disease Investigation Officer, Poona.
<i>Kenya :</i>	Dr. E. M. Chenery, Director of Tea Research Institute.
<i>New Zealand :</i>	Mr. A. J. Johns, Plant Chemistry Division, D.S.I.R.
<i>Nigeria :</i>	Mr. J. West, Plantations Manager, West African Institute for Oil Palm Research. Mr. J. M. A. Sly, Agronomist, West African Institute for Oil Palm Research.
<i>Poland :</i>	Dr. M. W. Oleksiak, Pomology Experiment Station. Messrs. S. Mosinski and R. Kowalik, Institute of Organic Chemistry, Warsaw.
<i>Sierra Leone :</i>	Mr. H. D. Tindall, Horticulturist, Department of Agriculture.
<i>Southern Rhodesia :</i>	Mr. F. Puczykowski, Agronomist, Henderson Research Station.
<i>Spain :</i>	Señor G. Outhwaite, grower. Señor L. Massieu, Agricultural Engineer, Las Palmas.
<i>Sweden :</i>	Mr. R. Lamm, Horticultural Research Station, Alnarp.
<i>Switzerland :</i>	Dr. R. Fritzsche, Director-Designate, Swiss Experimental Station for Flowers, Fruit, Vine-growing and Vegetables, Wädenswil.
<i>Thailand :</i>	Mr. Kahn Jalavicharana, Chief of Plant Industry Section, Department of Agriculture.

U.S.A.:

Professor J. R. Culbert, Associate Professor of Floriculture, University of Illinois.
Professor S. H. Wittwer, Michigan State University.
Professor R. W. Fulton, Pathologist Agronomist, University of Wisconsin.
Dr. W. D. Holley, Colorado State University, Fort Collins.
Dr. Arden A. Sherf, Professor of Plant Pathology, Cornell University.
Dr. Floyd Smith, U.S. Department of Agriculture, Beltsville, Maryland.
Mr. Robert E. Nyland, Minnesota.
Dr. G. F. Warren, Department of Horticulture, Purdue University.
Dr. Robert E. Young, Research Professor, Vegetable Crops, University of Massachusetts.

West Indies:

Mr. S. Bharath, Department of Agriculture, Trinidad.

The number of United Kingdom visitors were too many to list in full, but we were particularly honoured by a visit from Mr. J. D. Godber, Parliamentary Secretary to the Ministry of Agriculture, Fisheries and Food on 11th May.

Meteorological observations

On the recommendation of the Meteorological Office the Ministry of Agriculture, Fisheries and Food consented to the setting up of an agro-meteorological station at the Institute under the Agricultural Meteorology Scheme. The standard equipment for running the station has been supplied by the Air Ministry, on loan. We are greatly indebted to these various bodies for their co-operation in providing a much needed service, as meteorological records are becoming increasingly necessary for our work.

The station is being run by the Horticulture Department, but records and information are made available to any member of the staff wishing to make use of them. Readings started on 1st January, 1960, and the first year's observations are summarized in a table in the Appendix.

Acknowledgments

It is again a pleasure to acknowledge the help of all those who have contributed so much to the Institute's further progress. The Governing Body have been a constant source of encouragement, as always, and have lent the weight of their help in numerous ways. Without the sympathy and support of the Agricultural Research Council, however, even their efforts would be of little avail, and we record with gratitude that we have had both in good measure. To the Institute's staff, of all grades, specially warm thanks are due for their enthusiasm and industry which have made it possible to record a most successful year's work. The Director is particularly indebted to the scientific staff for the accounts of their work which make up parts II and III of this Report.

The assistance we received from Mr. Morris of the N.I.A.E. and Mr. Musgrove of the Nuffield Foundation in designing the new plant pathology research unit has already been mentioned. The very friendly relations which have developed with the National Agricultural Advisory Service have also been mentioned; the collaboration we have received from various officers of that service, particularly the Directors of the Experimental Horticulture Stations, has again facilitated the Institute's work in many ways.

SUMMARY OF RESEARCH

In this issue we are reverting to a former practice and including a summary of the research work carried out during the past year, presented in a form which it is hoped will be more readily understood by the grower. Obviously it is only possible to refer to the more salient features of the work, and those who require a fuller account or more detail must consult the general and special reports from the research Departments and Sections which appear in later pages.

Developments during the year

We have begun to implement the recommendations of the A.R.C. Visiting Group, which as reported last year undertook a review of the Institute's research programme in the latter part of 1959, and have carried out such internal re-organisation as was immediately necessary.

The research programme continues to expand, and as already indicated has been extended into the field of nematology—the study of eelworm problems. The appointment of an additional plant breeder is enabling work on disease resistance and research on mushroom spawn to be taken up.

The tomato crop is of course the foundation of the glasshouse industry, and special consideration has been given to the intensification of research on this crop in the light of representations made by the West Sussex growers. One outcome has been the setting up of a research group to bring together workers on cultural problems at the three institutes engaged in this field—John Innes, National Institute of Agricultural Engineering and ourselves—in order to avoid duplication and to ensure co-ordination of effort where possible. Proposals for additional experiments to follow up basic work at the Institute were made and submitted to the A.I.C. Glasshouse Working Party. The facilities at the Experimental Horticulture Stations are already strained, but with the ready co-operation of the Directors concerned it has been possible to accommodate some new experiments at these stations.

The cucumber breeding programme has had to be slowed down in order to release glasshouse space for urgent work on the problem of red spider mite resistance, a problem which is assuming serious proportions in the Lea Valley.

The problems of mushroom growing continue to receive the widest possible attention, and nearly all Departments and Sections now have a stake in this work. The integration of mushroom research with the rest of our programme has undoubtedly been all to the good, and has made for a very much stronger effort in this field than might otherwise have been possible. To guide us in our work with this crop we have the advice of the Mushroom Growers' Association Research Sub-Committee which met at the Institute on two occasions to see the work in progress and to discuss future plans. The opportunity that these visits provide for a full and frank discussion of the problems involved with leading members of the industry is very valuable.

During the year we have given special thought to the problems of the bulb industry and have attempted to frame a comprehensive programme of research. At the end of March the Director, accompanied by Dr. Winsor and Mr. Messing of the Chemistry Department, visited Kirton Experimental Husbandry Farm in Lincolnshire to discuss with the Director of that station and other members of the N.A.A.S. staff the future of bulb work there. Any programme of bulb research drawn up for the Institute must of course be backed by field experiments in the main bulb-growing areas, and it is pleasing to know that we can count on the full co-opera-

tion of those in charge of affairs at the Ministry's stations situated in those areas—Kirton E.H.F. and Rosewarne E.H.S. It is worth mentioning that a fair measure of attention is already being given to bulb problems; Dr. Winsor has become sponsor of the sand culture work at Kirton Experimental Husbandry Farm, Dr. Broadbent is continuing the work he started on narcissus viruses at Rothamsted, and Miss Smith, in the Crop Protection Department, is investigating problems associated with the control of leaf diseases which are such a trouble in the south-west of the country. The stem and bulb eelworm of tulip and narcissus will figure high on the list of the work to be undertaken by the newly appointed nematologist, and our co-operation has also been invited in a programme of anemone selection at Rosewarne Experimental Horticulture Station to try and isolate strains which will grow more satisfactorily in the south-west.

In the autumn we revived the practice of holding staff colloquia to enable members of the research staff to give an account of their work and future plans to their colleagues, who then have the opportunity of asking questions and joining in a general discussion of the subject afterwards. This does much to bring the research workers together and ensures that our efforts are thoroughly co-ordinated; it is intended that it shall become a regular feature of the Institute's scientific life.

PLANT BREEDING

The Plant Breeding Section under Mr. L. A. Darby continues to give most attention to the tomato, but useful programmes on cucumber and lettuce are in progress. Shortly, as mentioned above, it is hoped to extend the work to include a programme of anemone selection at the Rosewarne Experimental Horticulture Station.

Tomato

The progress made with tomato breeding gives every cause for satisfaction, and as already mentioned in the introduction the new compact-habit varieties have aroused so much interest among growers that seed has been distributed on a wide scale for commercial trials during 1961. The distribution was made first to those supporting the Institute through the Subscription Scheme, and then to growers registered with the Tomato and Cucumber Marketing Board, the Governing Body's decision being that one quarter of the available seed should go to the former and three quarters to the latter. Hasty arrangements had to be made to collect the seed by growing plants in pots in the latter part of the season, and in the outcome sufficient was collected to give each grower who applied for it, and who grows the crop under the conditions for which the new varieties have been bred, enough seed to undertake a reasonable trial. It must of course be realised that this was an unusual exercise for a research institute and was only undertaken because of our anxiety to meet growers' plain wishes that the new material should be made available to them at the earliest possible moment.

The new varieties were all derived from the initial cross 'Baby Lea' $\times$ 'E.S.5' and are the result of eight or nine generations of inbreeding. They should be almost true-breeding and are straight varieties, not hybrids. Some twenty or so lines were selected, varying only in fruit size, and as far as possible growers were given seed of two contrasting varieties. Apart from this difference in fruit size there should be nothing to choose between them. They are all compact in their vegetative habit and owe this to the 'Baby Lea' parent, but they have much better fruit quality introduced from 'E.S.5'.

The varieties have been released under the code numbers GCR 2 to 25 until such time as the best among them, as judged by growers' reports, can be decided upon and proper arrangements made for distribution of seed to the trade, when they will be suitably named.

It must be emphasized that these new varieties do not represent the ultimate objective of the tomato breeding programme, but are a by-product—as Mr. Darby terms it—thrown off at an intermediate stage which it has been decided to place in the hands of growers because of the interest they have shown in it. While giving them improved material at an earlier date than might otherwise have been expected, their trials with it will give them valuable experience in handling similar compact-habit material which should come out of the breeding programme at a later stage. In this longer term programme an attempt is being made to introduce the compact-habit character into several existing commercial varieties in order to make them more acceptable to growers who grow their crop under conditions tending to produce vigorous vegetative growth. Ultimately it is hoped to produce desirable hybrids between these new types, and some have already been produced for preliminary trial in 1961.

A somewhat similar programme is in progress to transfer the uniform-ripening character, giving freedom from “green-back”, into the standard varieties ‘Ailsa Craig’ and ‘Potentate’, and seed of these new varieties, as well as of a compact-habit form of ‘Moneymaker’, has been distributed to a few selected growers for trial under commercial conditions in 1961.

With the appointment of an additional plant breeder it has been possible to enter a new field, breeding for disease resistance. Among the problems we plan to tackle are the control of tomato mosaic virus, leaf mould (*Cladosporium*) and *Botrytis*, and wild and cultivated tomato species and varieties are being collected to see whether they contain any useful resistance factors. The John Innes Institute have been kind enough to pass on to us for further development certain *Cladosporium*-resistant stocks on which they have been working, and we are greatly indebted to them for facilitating our work in this way.

Grafting, which now seems to be practised in Holland on an extensive scale as a means of controlling the root troubles commonly experienced in glasshouse soils, is receiving our attention, and a small trial of the technique was done as a preliminary to further work. Good results were obtained.

Cucumber

As already mentioned cucumber breeding has had to be slowed down, but before this decision was taken a yield trial was conducted to test the effects of inbreeding the two standard varieties ‘Butcher’s Disease Resister’ and ‘Telegraph’ and to compare hybrids between them when produced from outbred and inbred parents. Further work has been done in the programme which aims to modify the variety ‘Butcher’s Disease Resister’ to give fruit with a shorter neck or “handle”.

Lettuce

Good progress is being made with lettuce breeding, the main object being to produce a variety with a paler colour to meet the wishes of Lancashire growers. Trials were conducted both at the Institute and at the Fairfield Experimental Horticulture Station. Another useful line of work is the cleaning up of commercial stocks of ‘Cheshunt 5B’, which have become very mixed, by single plant selection; the selected lines show great improvement even after only two generations.

CHEMISTRY

The work of the Chemistry Department, under Dr. G. W. Winsor, has been primarily concerned with the nutrition of glasshouse crops and with the composition and biochemistry of tomato fruit. The nutrition work has been extended to include outdoor early-flowering chrysanthemums in a joint experiment with the Horticulture Department. The special problems of manganese toxicity and soluble salts in glasshouse soils have continued to receive attention, but the investigations on mushrooms and loamless composts have been transferred to the Horticulture Department.

Nutrition of glasshouse crops

The experiments on the nutrition of glasshouse crops cover a wide range and, as mentioned, have been extended to include work on early chrysanthemums grown out of doors. The experiments are mainly of a long term nature, and are basic to an understanding of the fertilizer and manurial requirements of the crops studied. They are for the most part factorial experiments, that is to say, they investigate a number of factors (fertilizer treatments) and the possible interaction of one with another. The experiments are comprehensively planned, along modern statistical lines, as only in this way can the complex questions of plant nutrition be satisfactorily studied.

They are accompanied by chemical analyses of the soil and plant material in order that the responses to fertilizers can be properly assessed in relation to the initial fertility of the soil and their uptake by the plant. The object is to build up a detailed picture of the nutrition of the crop which will lead to a thorough understanding of its fertilizer requirements under various conditions. In this way we hope that the results can be widely applied.

Tomato

The tomato is receiving the greatest attention, for although this crop has been the subject of numerous fertilizer experiments over many years, there are still many questions unresolved. In fact, it is only now that we have available at the Institute adequate glasshouse space in which to do the type of experiment mentioned that the problems can be satisfactorily studied. The trend of much of the work to date is to the effect that it is the balance of nutrients in the plant that is of importance, and the interaction of one fertilizer with another can only be investigated in factorial experiments.

In 1960 a wide range of responses was obtained in the main tomato nutritional trial (in Block B), and some of them are mentioned in Dr. Winsor's report. The most striking results were those showing the effect of potash in improving fruit quality, some data on this being given in the report.

Liquid feeding of tomatoes has received special attention in the course of this work, and a new experiment was started to compare various sources of nitrogen as constituents of a nutrient solution. The nitrogen sources were urea, ammonium sulphate, ammonium nitrate and a mixture of potassium and sodium nitrates. The experiment gave a significant response in terms of both yield and fruit quality, showing that the source of nitrogen used does matter, but it will of course be necessary to repeat it before firm conclusions can be drawn.

The work on magnesium deficiency in the tomato has been rounded off, and a final experiment again showed that there was nothing to be gained by correcting the chlorosis with applications of magnesium, except perhaps where potash was applied at a high rate. In the four

years of the experiment the yellowing of the leaves which is characteristic of magnesium deficiency was readily corrected by magnesium applications, but a definite yield response to magnesium seems to have been obtained only in 1959, when the weather was unusually bright and sunny, and then only in the "high" potash treatment. It thus appears that the tomato plant will normally tolerate magnesium deficiency without any significant loss in yield, but that nevertheless under certain conditions, as in 1959, a serious loss of crop can result if the deficiency is not corrected. A full account of this work is being prepared for publication.

Carnation

Turning to carnations, the first nutritional trial was brought to an end in April, 1960, having run for nearly two years. In this experiment three rates of nitrogen and two rates of potash, applied as a liquid feed, were tested in every combination with or without phosphate, magnesium sulphate or lime in the base dressing, giving 48 different fertilizer combinations (treatments) in all. Some of the observed responses have already been mentioned in these reports, and a full account of the experiment will be published in due course. One interesting result was that with both of the varieties in the trial, 'William Sim' and 'Saugus White', splitting of the calyx was markedly reduced as nitrogen was increased.

A second experiment along similar lines was started in May, 1960, although this time magnesium was left out of account. Four rates of nitrogen and three rates of potash, again applied in solution, are being tested in every combination with four rates of phosphate and two of lime in the base, giving 96 treatments in all.

The nutritional requirements of the carnation have received very little study in the past, but these two comprehensive experiments should provide a good basis of knowledge. Already results of great practical interest have emerged.

Lettuce

The trials with lettuce of the residual effects of the fertilizers used in the main tomato nutrition experiment in Block B have proved extraordinarily interesting, and have shown that the lettuce plant is extremely sensitive to nutrition. Of particular interest has been the incidence of suspected manganese toxicity in some of the plots, and analytical work has been carried out to determine the relation between manganese uptake and toxicity symptoms and manurial treatment and soil pH.

Chrysanthemums

For lack of glasshouse space our work on chrysanthemums has to be largely confined to the outdoor crop. The first experiment on nutrition, with the variety 'Sweetheart', gave results of interest, the main responses being from nitrogen and organic manure. As with all the work on crop nutrition, soil and leaf samples have been taken for chemical analysis so that the field responses can be properly interpreted.

Manganese toxicity

During 1959 considerable difficulty was experienced in growing lettuce in steamed soil as test plants in the work on soil salinity. The trouble was ultimately diagnosed as manganese toxicity, and similar symptoms were seen in winter lettuce grown in the border on the main nursery. Subsequently the symptoms were seen in tomatoes and carnations in the nutritional trials at the Institute, and they have begun to assume importance elsewhere.

The problem of manganese toxicity has therefore been taken up in the research programme. The first experiment, using lettuce as a test plant in a potting mixture of steamed loam and peat, was designed to study the effects of lime and phosphate, but unfortunately, on this occasion, the amounts of manganese released on steaming were not quite sufficient to produce definite toxicity symptoms. Nevertheless, much useful information was obtained on the way in which the various treatment combinations influenced manganese levels in both soil and plants.

In another experiment eleven different varieties of lettuce were included to see whether there were any differences in their susceptibility to manganese toxicity. Again it was unfortunate that visual symptoms of toxicity could not be produced, but chemical analysis showed that there were marked differences in the amounts of manganese in the lettuce plants. It was interesting that the two Cheshunt varieties ('Early Giant' and '5B') showed the highest manganese content.

Soils from different sites at the Institute have since been examined to determine how much manganese they release on steaming, and one that has been found to release a great deal will be used for future experiments.

Soluble salts in glasshouse soils

Work on the problems associated with excessive soluble salts in glasshouse soils has hitherto concentrated on the technique of measuring their amount, as the conventional *pC* test is not always satisfactory and is particularly likely to give misleading results in the case of old glasshouse soils which have large accumulations of calcium sulphate. In 1960 various methods were used for estimating soil salinity in experiments designed to determine to what extent the water-holding capacity of the soil influences the relation between salinity and growth, using lettuce as a test crop. A mass of data has been assembled, and much statistical work will be required before firm conclusions can be drawn.

The composition of tomato fruit and its relation to quality and flavour

The chemical composition of tomato fruit has been studied over a number of years, and a wealth of valuable information has been obtained. The many nutritional trials and other experiments in progress at the Institute provide an excellent source of material for this work, and it has been possible to determine the effect of numerous factors, cultural or otherwise, on the chemical constituents of the fruit. Routine analytical procedures developed at the Institute have considerably facilitated the work.

The main constituents determined are the sugars and acids, as well as the total solid matter present. It is believed that the flavour of the fruit is very largely dependent on these constituents, so the work has an obvious bearing on a subject of considerable topical interest. It is becoming increasingly recognized that although flavour counts for nothing in the markets at present, serious attention will have to be given to the production of fruit of the best possible flavour, whether by correct choice of variety or cultural conditions, as one more way of helping growers in this country to meet the competition of imported fruit. The problem is a complex one, and much will depend on consumer preference, but the work on the chemistry of tomato fruit which is being done at the Institute is providing a sound basis of knowledge of the factors most likely to influence flavour.

During 1960 the analyses covered very much the same ground as in the previous two years, but were extended to include a comparison of fruit from virus-infected and uninfected plants and an investigation of the effects of leaf and fruit restriction on fruit composition.

Numerous analyses were done on samples of fruit from the various nutritional trials, and reference should be made to Dr. Winsor's report for some of the findings. Fruit from seven different varieties grown under similar conditions were again analysed, and statistical examination of the data showed that there were highly significant differences between varieties in acidity and total solids. From these and earlier studies it has been concluded that acidity is probably the most characteristic feature in the composition of fruit of different varieties grown under one set of conditions, varieties differing far more consistently in the acidity of the fruit than in total solids or sugar content. It is noteworthy that the widely grown variety 'Potentate' is among the least acid.

Further analyses were done on samples of fruit from the cultural trial at the Lee Valley Experimental Horticulture Station at Hoddesdon sponsored by the Institute in extension of the work on fruit-ripening disorders. Although only tentative conclusions can be drawn as yet the preliminary results show that much interesting information can be gained by applying the analytical procedures to studies of this type and that cultural factors (shading, watering, temperature) are likely to have important effects on the chemical composition of tomato fruit.

When virus-infected fruit from the Virology Department's experiment was analysed it was found to have more sugars and total solids than uninfected fruit. The reason for this is uncertain, but it may be associated with the reduced yield from plants infected with virus.

The non-volatile acids of tomato fruit

In order to study more fully the changes in acidity in the fruit, as observed in the investigations reported above, complementary work has been done on the individual non-volatile acids, of which the two most important are citric and malic. Citric acid accounts for some 50-60% of the total acidity of good quality ripe fruit, and malic acid for between 15 and 25%, but the ratio of the two acids differs markedly between varieties.

The changes in the proportion of the two acids during the development and ripening of tomato fruit have been studied, and preliminary results show that while malic acid is dominant in immature green fruit its concentration falls off rapidly with ripening while that of citric increases, although the latter reaches a peak value with the first appearance of colour in the fruit.

The biochemistry of tomato fruit: pectic substances in the fruit

A programme of biochemical work has been developed over the past three years and has concentrated on the pectic substances and associated enzymes of tomato fruit as a further contribution to our knowledge of the ripening process. It seems likely that the pectic enzymes are associated with the softening of tissues which accompanies ripening, and hence studies of these enzymes should throw light on normal and abnormal ripening, a matter of very considerable importance to the grower.

During 1960 studies on the changes in the content of pectic substances and on the activity of one of the enzymes associated with their breakdown were continued with two varieties of tomato. They have also been studied in "blotchy" fruit, and a finding of some interest was that even the red areas of such fruit may be abnormal in some respects.

PLANT PATHOLOGY DIVISION

As previously reported the departments working on pest and disease problems have been amalgamated to form a Plant Pathology Division which is under the general supervision of

Dr. L. Broadbent, who himself devotes special attention to virus problems, particularly that caused by tobacco mosaic virus on tomatoes. The Division was expanded during the year by the setting up of a section for Nematology.

ENTOMOLOGY

The Entomology Department, under Dr. N. W. Hussey, has continued to give much of its attention to mushroom pests, while impetus was given to the work on Glasshouse Red Spider Mite by the difficulties experienced by Lea Valley cucumber growers in controlling this pest. Further work has been done on the leaf-miners affecting ornamental plants, but on the recommendation of the A.R.C. Visiting Group the white-fly problem is not being pursued for the time being.

Mushroom pests

Work has continued on Phorids and Cecids. An exceptionally heavy outbreak of the Phorid *Megaselia halterata* on a local farm provided an excellent opportunity for studying, on the field scale, the changes in insect population from spawning to the end of cropping. An astonishing finding was that there were several times more larvæ in the compost than were reported in the famous "Phorid" year of 1953, when the pest was so bad. This experience, taken in conjunction with the results of experiments in jars, has suggested a figure for population density at which serious damage to the mushroom mycelium, with its attendant effect on cropping, is likely to occur; this figure is 100 larvæ per 30 grammes of compost. Although there were vast numbers of flies present throughout the cropping season, the study of population trends showed that the number of larvæ declined steadily from three weeks after spawning and that few eggs were laid in the first week after casing when the trays were in the cropping house; this serves to emphasise that the greatest threat from this pest is during spawn run. Tests with insecticides carried out by exposing jars of newly-spawned compost in cropping houses with a high fly population showed that synergized pyrethrin dusts markedly reduced egg laying, but that BHC and malathion were of no value. Follow-up trials with pyrethrins applied in heavy doses to newly-spawned beds in the absence of flies suggested that there were not likely to be any cultural objections to the use of this material at normal doses.

Turning to Cecids, a series of experiments in the cropping house confirmed earlier work on the economic effects of an infestation. Loss results from contamination of the mushrooms with larvæ, making them unmarketable, and observations with *Mycophila speyeri* showed that contamination takes place when the larval population rises above a certain level. A study was also made on the spread of this species in large beds, following up similar work with *Heteropeza* last year. The most satisfactory control for Cecids has been obtained by incorporating aldrin in the casing, before application to the beds, at a concentration of 10 p.p.m., but growers have questioned whether this insurance measure is worth while. A trial was therefore undertaken to see whether it would be sufficient to apply aldrin to the surface of the casing when contamination of the mushrooms first becomes apparent. Although this seems likely to be of some value, it is safer to use the treated casing technique. In previous work no evidence was obtained of a significant loss of crop even with a heavy infestation of normal compost. Several attempts have been made to see whether there would be a greater effect if the mycelium were growing under poor conditions, but although some loss in yield was obtained with *Heteropeza* it is unlikely that comparable losses would be obtained in commercial practice.

Red Spider Mite

Early in the year our attention was drawn to the difficulties experienced by Lea Valley cucumber growers in controlling red spider mite, apparently because the pest was developing resistance to the chemicals (acaricides) used against it. It was therefore decided to undertake urgent work on this problem, and the necessary glasshouse space was made available by restricting the cucumber breeding programme.

Samples of mites from affected nurseries were received at intervals during the summer and tested for resistance, a special laboratory technique being developed for the purpose. This proved not entirely satisfactory for "Kelthane", but it was found that striking differences could be demonstrated when "Kelthane" was applied to the upper surface of leaves of growing plants, the mites being contained on the lower surface. While dipping tests showed that the chemical will give a complete kill if deposited on the mites, field strains appear to have different degrees of resistance to "Kelthane" translocated between the upper surface of the leaf and the lower surface where the mites are feeding. Poor distribution of spray on the under-surface of cucumber leaves may therefore explain the apparent resistance to "Kelthane" that growers have been experiencing.

Large scale field experiments to test the value of various materials for controlling red spider mite and to determine the effect of different degrees of infestation on cropping were attempted with a crop planted in July, but these had to be abandoned because the mites failed to build up on the plants even though they were deliberately infested on three occasions. The cause of this failure, which could be of considerable significance, was vigorously investigated, and evidence was obtained that the sulphur vaporizers, used to control mildew on the cucumbers, reduced the mite population markedly. Further work is being done on this.

The hibernation behaviour of the mite has been specially investigated because the pest has been reported as troublesome even in January and February in the Lea Valley, an observation inconsistent with the claims of earlier workers. There was a suggestion that there may be differences between strains in the relative balance between the length of day, temperature and nutrition needed to induce them to go into the resting stage.

The Department has done much to try and unravel the complex situation regarding the naming of greenhouse red spider mites in Europe and America, and investigations on the inter-relation of the various colour forms have been previously reported. The matter is of considerable importance in work planned for the future on the mechanism and inheritance of resistance to acaricides. In this Report is published (at p. 91) a special article on breeding studies carried out at the Institute to determine the status of European strains. The results show that the situation is less complex than was at first thought, and that there are in fact only two distinct species which occur throughout Europe and America. The natural ranges of these species are restricted by differences in resting-stage behaviour, but they often occur together in the artificial environment of glasshouses.

Leaf-miners

Work was started in 1959 on the leaf-miners affecting ornamental plants both under glass and outdoors. In the initial phase a survey of the species involved was undertaken, accompanied by experiments on the factors inducing feeding and egg-laying on different plants. These studies were continued during the past year, and particular attention was paid

to the parasites of the species *Phytomyza atricornis* which can be found on a wide range of host plants. During the course of the latter observations evidence was obtained to suggest that the species may, in fact, consist of several strains with different, but overlapping, host ranges.

NEMATOLOGY

It has already been mentioned that the research programme is being expanded to include the study of eelworm problems. For this purpose a Nematology Section, under Mr. J. J. Hesling, has been set up in the Plant Pathology Division. Mr. Hesling did not assume duty until December and spent the few weeks available to him in arranging a laboratory and in obtaining a minimum of equipment necessary for future work. Construction of special apparatus, to be fitted up in the field laboratory, was also begun.

Although there is nothing further to report at this stage it may be of interest to mention that the new Section will undertake two main lines of work, the study of eelworms found in mushroom beds, and the investigation of the stem and bulb eelworm, *Ditylenchus dipsaci*. The latter is a particularly serious threat with tulips, but the narcissus eelworm is especially troublesome to growers who produce bulbs for sale, as only a slight infestation may make a crop unsaleable. There is evidence that the existing eelworm control by hot-water treatment is less effective than hitherto, the eelworms now requiring a higher temperature to kill them; the efficiency of the treatment is therefore to be investigated, first by developing a technique for measuring its physical and biological effects.

As regards mushroom eelworms, these are common in the compost, particularly towards the end of cropping, but there is much to be learned about their role. The biology of the different species occurring is to be studied, with special reference to their origin and spread, to their persistence in the absence of food and to their resistance to desiccation and peak heating.

MYCOLOGY

Certain rather intractable problems of the glasshouse and mushroom grower continued to enage the attention of Mr. P. H. Williams and his colleagues in the Mycology Department; these are *Didymella* Stem Rot of the tomato, Carnation Wilt diseases, Cucumber Mildew, and Watery Stipe disease of mushrooms. New work was started on *Verticillium* Wilt of the tomato and on Cucumber Black Rot, while further observations were made on Petal Blight of chrysanthemums.

Didymella Stem Rot of the tomato

Following up last year's work an experiment was done to find out how important the handling of plants is in the transmission of *Didymella* disease. The results indicated that the usual cultural operations involved in trimming the plants, whether carried out with a knife or by hand, was not likely to be an important way of spreading the disease.

With the increasing use of chemicals, particularly metham-sodium, for sterilizing glasshouse soil in place of steaming, their value in controlling *Didymella* is of special interest. Steaming makes soil very susceptible to infection by the fungus, because of the destruction of competing organisms, and there can be a resulting high incidence of disease in a subsequent tomato crop. It is obviously important to know whether chemical sterilizers are likely to behave similarly. For lack of glasshouse space the matter had to be investigated

in the laboratory, but the results were encouraging in suggesting that the chemicals tested, chloropicrin and metham-sodium, would eliminate *Didymella* from infected glasshouse soil.

Verticillium Wilt of the tomato

During the war years work was taken up at the old Cheshunt station on the wilt disease of the tomato caused by the fungus *Verticillium*. This led to the recognition of the importance of the species or strain of the fungus in relation to the diseases caused by it, not only on the tomato but also on other crops. The work was dropped at the end of the war, but it has now been resumed at the Institute where the facilities required are rather better.

Various isolations of the fungus have been made and their effects studied when inoculated into tomato plants.

Cucumber Black Rot

Another new line of work which has been started is an investigation of the disease of cucumbers caused by the fungus *Mycosphaerella melonis*. The disease is a potentially serious one as given the right conditions for spread it can cause considerable damage, particularly as the fungus sometimes attacks the stem of the plant. Inoculations made on plants growing in large pots, however, proved unsuccessful in infecting the stems, possibly because growing under such conditions the stems were too thin and hard for ready infection by the fungus.

Cucumber Mildew

Further experiments were done to clarify the host range of the fungi causing mildew on cucumbers and other plants. No cross-infectivity could be demonstrated between plaintains and cucumber, but sowthistle was still highly susceptible to cucumber mildew. Work on the problem of alternate weed hosts for cucumber mildew has now been discontinued.

Carnation Wilt Diseases

The experiment in one of the trial glasshouses to determine how long the fungi causing wilt diseases of the carnation will survive in the soil was continued, but no success was obtained in isolating the fungi from soil in which tomatoes or chrysanthemums had been grown after an infected carnation crop. Attempts to isolate the fungi from the roots of chrysanthemums growing in infected soil were also unsuccessful. Nevertheless some plants wilted when potted in soil from plots inoculated with *Verticillium cinerescens* in 1959 and which had grown tomatoes for two seasons. Carnations planted in plots which had borne diseased carnations the previous year also wilted more rapidly than did the previous crop, indicating a build-up of infection.

Petal Blight of chrysanthemums (*Itersonilia perplexans*)

In the course of further work on this disease the fungus was isolated in late autumn from many blooms of outdoor chrysanthemums, dahlia and sunflower. The conditions necessary for the development of the fungus are now being studied.

“Watery Stipe” disease of the mushroom

Miss Gandy has pursued her work on this important disease, which still presents a worrying threat to the industry. Experiments were carried out both in the cropping house and in the laboratory.

In one of the cropping house experiments it was found that the time of "infection" was of great importance in determining the seriousness of the effect of the disease on cropping. Cropping was reduced by about one half on beds inoculated at spawning, and by about one third on those inoculated at casing, while the effect of later inoculations was negligible. This was on beds twelve feet long by four feet wide. Although abnormally shaped mushrooms were common on beds inoculated at the earlier stages, similar abnormalities occurred later on the control plots, and they were also observed in other unrelated experiments in which the same strain of spawn was used. To test whether the abnormalities referred to had a genetic origin a spawn trial was undertaken, testing eight commercial spawns at two spawning rates. It was found that one type of abnormality, similar to those associated with "Watery Stipe" disease, was common, and that the frequency of its occurrence varied with the strain of spawn. These results have helped in choosing a strain, for use in future "Watery Stipe" experiments, which produces the fewest abnormalities.

When growers suffer an outbreak of "Watery Stipe" disease it is important to know what steps they can take to avoid further trouble. A useful experiment bearing on this was undertaken, the object being to see whether the "cooking out" of a mushroom house at the end of cropping would effectively disinfect it after an outbreak of the disease. Infected compost which had been heated at 42°C. for twelve hours was inoculated into beds at spawning time, but they produced healthy crops, so presumably cooking out would be effective.

In the laboratory the work was directed towards determining the nature of the infectious principle associated with "Watery Stipe" disease. The difficulty has been to isolate it from the cells of the mushroom mycelium, and none of the numerous methods tried was successful. Other methods used to extract a possible virus also failed. As a rather long shot a range of test plants such as are used in virus investigations was inoculated with a suspension of "diseased" mycelium, but the results were negative, and no success was obtained in an experiment designed to see whether *Cecid* larvæ might transmit the disorder. Thus although there is no doubt that "Watery Stipe" disease is an infectious disorder, resembling a virus disease, no definite evidence has yet been obtained of the occurrence of a virus in affected mycelium, neither has any natural means of transmission yet been demonstrated.

VIROLOGY

Although the work on virus diseases is still considerably handicapped by lack of facilities (which are soon to be provided—see page 13), a very full programme has been undertaken and much progress has been made. The programme includes an all-out attack on the problem of tobacco mosaic virus in tomato, undoubtedly one of the major problems of tomato growing. Among the ornamentals work is concentrated on the carnation and chrysanthemum, but several others are receiving attention. We have been fortunate to obtain a very high speed centrifuge—a most expensive item of equipment—and this has made it possible to develop some of the specialised techniques which are nowadays essential for the study of virus diseases. Mr. Hollings' visit to the United States was also of great value in affording him the opportunity of studying techniques developed in that country. Mr. Hollings was able to give as much as he received, however, and the visit led to a most useful exchange of information with American workers. In particular, tests with antisera taken to the U.S.A. showed that some of the American and British viruses of ornamentals are identical; this will be of the greatest value in comparing future work on these diseases in the two countries.

Carnation viruses

Much of the current virus research at the Institute is devoted to carnation viruses. Perhaps the most surprising finding has been that all commercial varieties of carnation so far tested, including some first- and second-year seedlings, have been infected with mottle virus, and while in the U.S.A. Mr. Hollings found that every one of 230 carnation plants tested was similarly infected. It thus seems almost certain that all carnation plants in commercial culture are infected with mottle, and this is a decided complication in work designed to assess the damage caused by this and other viruses, which of course demands virus-free plants for comparison. So far there has been no indication that any of the carnation viruses is seed-borne, so seedlings of 'Joker' and several of the Sim varieties have been raised to provide virus-free plants for the purpose.

Carnation mottle virus has received much study, and tests showed that it is very similar to ringspot virus in some respects, making the separation of these two viruses difficult. Fortunately ringspot can be eliminated by heat-treatment or by tip culture, whereas mottle cannot. The reason for the latter has become clear from assays of the concentration of mottle virus in different parts of the shoot tip which have shown that the virus may be present even in the meristems themselves.

Further work has been done on tip culture as a means of eliminating carnation viruses. For the most part some 30 to 40% of shoot tips rooted, although the proportion depended on the size of the tip taken, and tips from 'William Sim' consistently rooted better than those from 'White Sim.' Complementary work on the distribution of mottle virus in the shoot tip has suggested, however, that although the smallest tips may be free from virus any that include the rudimentary leaf initials will not be so. Different culture media are therefore being tested to obtain the maximum rooting with the smallest tips. Clearly there must be an advance in technique before tip culture can be safely relied upon as a means of freeing plants from virus.

Several new viruses of the carnation have been identified at the Institute since Kassanis first described four in 1955, and among these is one to which the name "etched ring" has been given. An account of this hitherto undescribed virus, which seems to be quite prevalent both in this country and in the United States, is given in a special article on page 94. The symptoms are particularly severe and conspicuous on the variety 'Joker', which is being used as an indicator plant.

Chrysanthemum viruses

Further work has been done on the stunt virus, which in its American form presents a real threat to the chrysanthemum industry. The standard test for this virus is to graft scions from the plant suspected of carrying it to the chrysanthemum variety 'Mistletoe', but the diagnostic symptoms often take several months to show up. Attempts to reduce this long incubation period by growing the indicator variety at higher temperatures proved unsatisfactory. To try and develop a rapid diagnostic test for indexing chrysanthemums work has continued on the purification of stunt virus. So far it has not proved possible to eliminate stunt virus by heat treatment or by tip culture after heat treatment.

The various leaf-mottling viruses have received further study with a view to determining their relationship and their occurrence in different chrysanthemum varieties. The survey has shown that in many instances an entire variety may be infected.

Other ornamentals

The viruses of dahlia and pelargonium have been investigated further, and some attention has been given to the ringspot virus of hydrangea. The occurrence of cucumber mosaic virus in some shrubs, and a suspected virus disease of oleander have also been studied.

The leaf curl virus of pelargonium is of unusual interest. Usually the symptoms are seen only during the winter, and the virus seems to disappear from the plant during the summer. Recent work has shown that the virus may apparently be dormant in the plant for some years before it can again be detected in cuttings or by grafting to an indicator plant.

Tomato mosaic

There is perhaps no problem of tomato growing more serious, and at the same time more difficult to overcome, than the disease caused by tobacco mosaic virus ("tomato mosaic"). While many growers would subscribe to this view, there are few who would be prepared to hazard a guess at the losses caused by the virus. Although many claims are made there is no certain way of avoiding the disease, and few crops are ever entirely free from it. We need make no excuse, therefore, for the concentrated effort that is now being made at the Institute, under the directions of Dr. Broadbent, to solve some of the many outstanding questions concerning it. Tobacco mosaic virus, because of the ease with which it may be handled, has received more attention by scientists the world over than any other plant virus, and a very great deal is known about its properties. Tomato mosaic has also been the subject of countless experiments over many years, yet the disease is still a serious practical problem.

The approach made at the Institute has therefore been to start at the beginning, assuming nothing that has not been proved absolutely beyond doubt by previous experiment, and by a carefully planned programme endeavouring to clear up one by one the many uncertainties regarding the epidemiology of the disease and the losses it causes. As a prelude to this work Dr. Broadbent has undertaken a very thorough search of all the available scientific literature, and a critical review of it is published in this report (page 96). This is the orthodox way of beginning any scientific investigation, and in passing it may be mentioned that, as will be evident from past reports, it has been our policy to publish these reviews of the literature because of their general interest.

The emphasis has so far been on preventing infection, and last year we reported the work that had been done on various possible sources of virus in a tomato crop, including seeds, glasshouse structures, workers' hands and clothing. This attack on the problem has been continued, and has been extended to include smoking tobacco and soil.

Another large batch of seeds was sown, without pricking out, under conditions of isolation with every precaution taken to prevent contamination, but no infected seedling grew although virus (TMV) was shown to be present in or on the seed coat. When seedlings were pricked out, however, a small proportion of them showed virus soon after. Thus seed can be a source of infection in normal commercial practice. Treatments that have been recommended for freeing tomato seed from virus have been compared, but none has been found to eliminate it entirely, although many treatments apparently reduce the concentration of virus without affecting germination.

Numerous samples of tobacco have been tested, and in nearly every case were found to contain a strain of TMV which was not the same as that in infected commercial tomato

crops, from which 60 samples of foliage were tested. This evidence suggests that tobacco is not a common source of virus in tomato crops, but this work will be done on a wider scale before a firm conclusion is drawn.

In a carefully devised experiment to determine the importance of soil contamination a small proportion of plants were infected when grown in soil that had grown a diseased crop the previous year. It seems, however, that the chemical soil steriliser, metham-sodium, may greatly increase the amount of infection. This is a finding of considerable importance which will be investigated further. In other experiments evidence was obtained that infection through root-contact in the soil is not common.

Perhaps the most open question concerning tomato mosaic is the extent of the loss caused by the disease. That the effect of the virus on the growth of the plant is damaging will be evident to anyone, but there are few reliable figures for glasshouse-grown tomatoes. It was therefore decided to lay down a carefully controlled experiment to obtain information on this point, and a whole vinery house was devoted to it. Details will be found in the Virology Department's report, but it may be mentioned here that the experiment involved a tremendous effort in order to ensure that the treatments went according to plan and, in particular, that the control plots remained uninfected. This meant extremely strict hygiene measures, the success of which may be gauged by the fact that five out of the six control plots remained healthy until the end of the experiment.

Three infection dates were used in the experiment, and the effects of the virus differed with the time the plants were infected. Nevertheless, the loss in crop over the whole season was about the same for each infection date, averaging 15%. The effect on fruit quality differed considerably with infection date, however, being particularly severe with the late infection (31st May). Because of the effect on fruit quality the later infection caused the greater financial loss.

This was of course a single experiment in one year under one set of conditions, and although it was based on two varieties (which behaved similarly), we should not make too much of the results until confirmatory evidence has been obtained. They are, however, very suggestive as showing the order of loss which may be caused by tomato mosaic.

CROP PROTECTION

The work of the Crop Protection Department, under Mr. W. H. Read, has continued on much the same lines as in the past, but the investigation of control measures for Red Spider Mite have been given greater priority in view of the difficulty of controlling this pest, particularly on cucumbers in the Lea Valley, apparently because of the emergence of strains of mites resistant to chemicals which are safe to use on this crop. This investigation is being undertaken jointly with the Entomology Department, and some of the work is described in the report of that Department. Soil sterilisation with chemicals, as compared with steaming, has received further study, particular attention being paid to the action of metham-sodium. An interesting turn has been given to the search for an efficient and safe fungicide for controlling mildew on cucumber by the finding that excellent control can apparently be obtained by vaporizing sulphur in special apparatus; this is receiving careful investigation as there is some indication that sulphur vapour may also be of value in controlling Red Spider Mite. More work has been done on problems associated with the control of narcissus leaf diseases, an investigation started last year to assist growers in the south-west where these diseases are often serious.

Soil sterilisation by chemicals

The long-term experiment started in the trial glasshouses in 1959 to compare chloropicrin and metham-sodium as soil sterilants with steaming was continued for a second year, with very much the same results, as far as yield responses were concerned, as in the previous year. The yield improvement, compared with the untreated control, was almost as good where the soil had been sterilized with chloropicrin or metham-sodium as where it had been steamed.

Of topical interest is the use of metham-sodium, the recommended common name for formulations containing the active chemical sodium methyldithiocarbamate. This is a soil sterilizer of great promise, but experience has shown that its use is fraught with some risk, harmful effects on plants resulting from the release of the subsidiary chemical, methyl isothiocyanate as a decomposition product in the soil. Although it is now usually possible to avoid trouble by scrupulously following makers' directions, further information on the conditions governing the release and dispersal of the harmful chemical, which is also believed to be the active fumigant, is desirable. An improved analytical method for measuring it in the small amounts remaining in the soil some weeks after treatment has therefore been devised and used to study the distribution and loss of the compound in soil treated with metham-sodium. A sensitive, but rapid and simple, method for detecting very small amounts of methyl isothiocyanate is also being tested in the hope that it will prove reliable in practical use; it would have an advantage over the use of test plants for deciding whether there was likely to be any risk of injury to plants put out in soil treated with metham-sodium. Attempts have been made to convert traces of methyl isothiocyanate to a less volatile and apparently less harmful substance by treating the soil with suitable compounds, but the preliminary results have not been promising.

Red Spider Mite

In the search for new chemicals for use against resistant red spider mites several potential acaricides were tested against a strain of mite known to be resistant to organo-phosphorous compounds (such as parathion) and slightly resistant to "Kelthane." The only substance showing any merit was one resembling the active principle of "Karathane", the mildew fungicide, but at the necessary dose it caused too much damage to plants.

A large scale glasshouse trial was undertaken in collaboration with the Entomology Department to test various materials for the control of Red Spider Mite, and to investigate particularly their distribution as applied under normal commercial conditions. It was thought necessary to make sure that the indifferent control of this pest now being obtained in some areas was not due to poor coverage of the plants through the adoption of new techniques of application. The materials used were petroleum oils and "Kelthane", both commonly used for the control of red spider, sulphur vapour and emulsified polybutenes. Sulphur vapour is primarily used to control mildew, a complicating factor in work with red spider at the Institute where mildew is usually very troublesome, but it was included as a separate treatment to see what effect it might have on red spider. Polybutenes have been used for the control of red spider in Canada; they control by mechanical means, trapping active stages of the mite by virtue of their stickiness.

The trial involved planting a late cucumber crop in July, four houses being devoted to it. The plants were inoculated with mites before setting out in the border and again on two later occasions, but to our surprise the infestation failed to build up and eventually the trial had to be abandoned. The cause of the failure may of course be of considerable significance

and was investigated with some thoroughness. There was a suggestion that it was due to the use of sulphur vaporizers which had of necessity to be used for the control of mildew, and the matter is to be explored further.

The polybutene spray was found to cause some damage to the cucumber plants at the higher concentration used, but the main problem with the use of this material is due to its very viscous nature. A series of less viscous grades has therefore been made for future testing.

Some work was done to try and determine the cause of resistance in resistant strains of mites.

Narcissus leaf diseases

Attention has been focussed on Leaf Scorch, the disease caused by the fungus *Stagonospora curtisii*, and in order to develop techniques for assaying chemicals for the control of the disease it has been necessary to study some aspects of the biology of the fungus. Some of the observations made by Miss Smith, who is carrying out the investigation, are included in the Crop Protection Department's report. The wax coating on the leaves seems likely to be important in determining infection by the fungus, and work is in progress on the susceptibility of foliage to spore infection at different stages of growth, correlating this with estimations of the amount of wax present on the leaf surface.

Thirteen chemicals formulated in different ways were tested for their power to eradicate infection in the leaf tips. Although some were promising none gave complete control. Work is also being done on the protectant activity of various fungicides against secondary infection.

Determinations of the amount of wax on the leaf surface of a number of varieties did not suggest that susceptibility to infection or to damage by sprays is related to the amount of wax present. The extent to which spray damage, which is particularly severe in the Isles of Scilly, is associated with other factors has therefore been investigated, and experiments have been made to see if the damage resulting from the use of Bordeaux mixture can be reduced by adding something to the spray.

Cucumber Mildew

Good control of mildew on cucumbers, a disease which can be particularly troublesome at the Institute, has been obtained with sulphur vaporized nightly in small quantities in an apparatus specially designed for the purpose. Tests on heavily infected plants showed that nightly vaporization of sulphur at the rate of one ounce per 50,000 cubic feet of glasshouse space protected the young foliage from infection and checked the development of the disease on older leaves infected before treatment began. So far no trials have been made to find out whether sulphur vapour has any harmful effect on cropping, but the treatment does not seem to harden plants more than routine applications of "Karathane."

HORTICULTURE

The new Department of Horticulture set up under Mr. Sheard is being steadily built up, and on the recommendation of the A.R.C. Visiting Group has taken over the work on tomato growth and fruit ripening disorders started in the Plant Physiology Department and the work on mushrooms formerly carried out in the Chemistry Department. As announced in the 1958 Report the new Department will undertake investigations of a horticultural nature which do not properly fall within the provinces of the other research departments; its functions are to define problems needing attention by the specialist departments and to take over the

results from those departments in the first stage of their application to commercial practice. New work initiated in the Department is on loamless composts and on carnation spacing, while in collaboration with the Chemistry Department a series of experiments on the manuring of early-flowering chrysanthemums grown outdoors has been started.

Tomato growth

The work on tomato growth, with its associated studies on fruit ripening disorders, had been taken to a very interesting stage in the Plant Physiology Department, and it is entirely logical that its further development on the field scale should be taken over by the Horticulture Department. During the past two years the emphasis has been on the effect of planting date and the age of the plant at planting on the growth pattern of the tomato. In one experiment sowings were made at weekly intervals throughout a period of just over a year (22/9/1959 to 11/10/1960), and weekly observations were made on the development of the shoot, leaves, flowers and fruit from germination until each plant was about ten months old. The volume of data collected is enormous, and it must inevitably be some time before it can be fully summarized, but already it promises to yield information of great practical value. The experiment was primarily designed as a check on earlier work, firstly to confirm the times at which there is a slowing down in the growth of the plant, and secondly to test the hypothesis that once fruiting is well established a constant ratio between leaf area and fruit volume is maintained except during the winter months.

Previously the check in growth that, with normal sowing dates, occurs in early May has been stressed, and it was at first thought that at this time of the year the days become too long for the maximum growth rate of the tomato to be maintained. The trial carried out at various latitudes, extending from Finland to Malta (see 1958 and 1959 Reports) did not support this idea, neither did observations made in 1960 on a few plants grown in specially constructed chambers in which the environment can be partially controlled. Other observations on the effect of day-length on the growth of the tomato, using natural daylight and covering the plants with opaque shields at stated times, showed that the growth rate declined very rapidly with daylengths between six and eight hours. This result is obviously of considerable significance when comparing, for example, the growth of plants in Guernsey and the Clyde Valley.

Previous work had shown that when tomatoes are grown under unrestricted conditions, that is to say, at a wide spacing and with adequate watering, the development of the first truss is arrested during the period between the autumnal equinox and the shortest day. As every grower knows, however, the truss can be induced to form if the growth of the plants is controlled by confining the roots, for a time, to a pot or other container before allowing them to grow out into the border. Although this practice is well known it is still a rather hit-or-miss business, and it is obviously worth further study experimentally. Such a line of work follows on quite naturally from the growth studies at the Institute, and experiments on the field scale have now been conducted for two years in which plants were set out in the border at various dates within the normal period for commercial planting, and were grown either without root restriction by direct planting into the border or in "whalehide" pots. In the second year the experiment was amplified to test other factors. The results will shortly be published in a scientific journal, but it may be mentioned here that the experiments have provided useful information on the effect of planting date on early and total yield, the trend being as might be expected, the earlier the sowing the greater the yield. The greatest interest, however, attaches to the effect of root restriction, and here it was found that while growing in "whalehide" pots did undoubtedly increase early yield, taking all plantings as a whole, there was no difference at the end of the season in the total yields obtained from plants grown

in the border and those grown in pots. Results of this kind are difficult to interpret in economic terms, and special consideration was given to this problem. A tentative method of overcoming the difficulty has been suggested in an earlier report (Cooper, A. J. *Rep. Glasshouse Crops Res. Inst.* 1956, 1957, pp. 33-39), and involves the calculation of an "equivalent market yield." When applied in the present experiments it was found that taken over the whole season there was little or no benefit from growing in "whalehide" pots. There was, however, an interaction with the night temperature at which the plants were grown, which may account for some of the conflicting results obtained in the past. As regards planting date, the economic assessment suggested that the earlier the planting the greater the return, even allowing for increased fuel costs.

Blotchy ripening of tomato fruit

Field experiments on the effect of glasshouse conditions and cultural treatment on the incidence of blotchy ripening and other fruit ripening disorders have now been carried out over two years at the Ministry's Lee Valley Experimental Horticulture Station at Hoddesdon, in Hertfordshire. It is hoped to publish the detailed results in a scientific journal, but some of the indications from the first year's results are given in the Horticulture Department's report. The experiments aroused considerable interest among growers, not so much for the effects on fruit ripening disorders as for the effects on the growth of the plants, and some of the yield responses are also given in the Horticulture Department's report. Taking the two sets of results together, the greatest proportion of uniformly coloured fruit was produced by the variety 'Ware Cross', grown under a dry moisture regime, kept cool by day and shaded, while the heaviest yield was given by 'Ware Cross' heavily watered, kept cool by day and unshaded. Again there is an obvious difficulty in interpreting the picture in practical terms, stressing the need for parallel economic studies.

Mushroom investigations

The special equipment developed for the study of the growth of mushrooms under controlled conditions has undergone satisfactory trials. It consists of eight small cabinets in which temperature, humidity and air flow can be controlled independently. In the course of the trials interesting information was obtained on the behaviour of the mushroom under various conditions, but the work will of course have to be widely extended, with greater replication, before firm conclusions can be drawn. The interaction of the various factors will be of particular interest.

It is a common experience of workers engaged in cropping experiments with mushrooms that the variability between plots receiving apparently identical treatments is high. Mr. Flegg has continued the investigation of this problem in collaboration with Mr. Cooke of the Statistics Section. The experiments showed that omitting to "trash" the beds after picking does not affect yield and reduces the cost of production, and the later the stage at which mushrooms are picked the greater is the yield and the less the labour required for picking. The choice of the stage at which to pick for maximum cash return depends on the relative prices of the various grades, however.

The casing layer in mushroom cultivation

The reason why a casing layer is necessary to induce the formation of mushrooms on a bed of compost is still a mystery, but work at the Institute has shown the importance of soluble salts as a factor controlling this phenomenon. Further experiments, which are reported in a special article at page 117, have established that there is a close correlation between

the time taken for cropping to commence, and the number of mushrooms produced, and the electrical conductivity of the casing. A re-examination of data from an earlier experiment has confirmed this. The correlation with electrical conductivity suggests that the effect is one of "moisture stress"—the sum total of forces opposing the extraction of water from the compost or casing by the mushroom—and apparatus is being developed so that the critical experiment, in which moisture stress is actually measured, can be carried out to prove or disprove the theory. In the meantime, the results do suggest a plausible explanation of the failure of the mushroom to fruit on compost alone.

Mushroom composting

We hope soon to investigate some of the problems of mushroom composting, and in anticipation of this work Mr. Flegg has undertaken a very useful survey of the scientific literature covering this field. This is published as a special article at page 125.

Loamless composts

Mr. Bunt has taken over the study of potting composts made without loam which was initiated in the Chemistry Department. The experience of growers everywhere, as well as difficulties encountered at the Institute, shows the urgent need for a formula to replace the time-honoured John Innes formula where the requisite grade of loam cannot be obtained.

Large scale experiments with numerous treatments have been carried out to test the value for plant growth of various combinations and ratios of peat, sand, vermiculite, perlite and clay. In addition, sedge and sphagnum peat have been compared, and the importance of the particle size of both peat and sand investigated. The experiments have shown that some plants are much more sensitive than others to their growing medium, and that, in particular, *Antirrhinum* and *Linum* are more sensitive than the tomato to both the physical and chemical properties of the medium. *Antirrhinum* in loamless mixtures has shown several growth abnormalities, including leaf distortion, chlorosis and loss of apical dominance. The work has also shown that much depends on the time of year at which the composts are used; during the period March to October tomatoes grow every bit as well in some of the loamless mixtures as in standard loam-based composts.

Carnation; planting density and date of planting

While waiting for facilities to become available at the Institute two experiments were laid down on local nurseries to determine the effect of spacing on the yield and quality of bloom of carnations, and we are grateful to the growers concerned for so readily co-operating with us in this work. These experiments were followed by a more comprehensive experiment, including also a study of time of planting, laid down in one of the carnation houses at the Institute. Some of the results obtained so far are mentioned in the Horticulture Department's report, but it must be emphasized that it is as yet too early to draw firm conclusions from this long-term series of experiments.

Chrysanthemum manuring

A study of chrysanthemum manuring has been taken up in collaboration with the Chemistry Department. A comprehensive experiment testing the responses to nitrogen, phosphate, potash and dung, each at three different rates and in every combination, was laid down on early-flowering chrysanthemums grown out of doors. While the first year's results are of interest, the experiment is to be repeated, with modifications, and not until it has run for a number of years will it be possible to draw firm conclusions.

NURSERY MANAGER'S REPORT

by

J. M. EVANS

The field trial glasshouses

The areas occupied by the main crops (*viz.*, tomatoes, cucumbers, carnations and winter lettuce) were approximately the same as in 1959.

All the glasshouses were steam-sterilized, with the exception of those in B block. To improve the physical condition of the border soil still further sedge peat was applied at the rate of 12 tons per acre, and more automatic irrigation equipment was used.

Numerous difficulties arose for lack of the badly-needed new propagating house, mentioned in last year's report, and its erection is still awaited.

Heating system

The alterations to improve the 4 in. hot water system as a temporary measure were described last year. The major re-organisation of the heating system is now in hand and will be completed during 1961.

Constructional work

Concrete beds were laid in the northern half of the carnation house E1 for work on Tobacco Mosaic Virus.

The area between the potting shed and propagating house No. 1 was concreted to facilitate pot storage, etc.

Two ranges of brick frames were built between propagating houses Nos. 1 and 2 to take 70 Dutch lights. One range will be heated.

General cropping

Tomatoes

Further increases in yield were obtained, notably in F and G blocks allocated to the Plant Breeder, where over 14lb. of good quality fruit per plant were recorded from the more promising varieties. Picking began on 14th April and ended on 19th September.

Cladosporium and *Botrytis* were controlled during the poor summer weather by frequent fungicidal applications, and success was achieved in all houses except D1, where the variety 'Immuna' succumbed to a virulent strain of Leaf Mould and resisted control measures to a large extent, and also in B block, where *Botrytis* attacked the weak plants growing in the plots with low levels of nutrition. Neither Red Spider Mite nor White Fly gave cause for frequent control measures.

Cucumbers

Two crops were again grown, the borders being steamed before each crop. On 18th January the houses were planted with new varieties for the Plant Breeder, and a quantity of seed was taken. On 24th June the houses were replanted with the variety 'Butcher's Disease Resister' for the Crop Protection and Entomology Departments for their work on Glasshouse Red Spider Mite.

Mildew again appeared early in the season, but this year greater success was obtained in its control by the use of electrically-heated sulphur vaporisers.

Carnations

Carnation houses E2 and E3 were both cleared and replanted, in May and July respectively, the rooted cuttings being direct-planted. E2 continued as a nutrition experiment with the varieties 'William Sim' and 'Pink Sim' in concrete beds, and E3 was put down to an experiment dealing with date and density of planting, using the varieties 'William Sim' and 'White Sim' in ground beds. The quantity and quality of flowers until the end of the year was very good. Liquid feeding of potash and nitrogen was practised throughout.

Lettuce

Seed was again taken from plants selected the previous winter, and this was sown on 1st November and planted in mid-December for cutting in February.

Block B was also planted with winter lettuce to be cut in February.

Research glasshouses and mushroom unit

Intensive experiments continued in the research glasshouses and mushroom unit, no major changes being made.

Outside field trials

Early chrysanthemums

A factorial nutritional experiment was laid down using the variety 'Orange Sweetheart', with guard areas of other Sweetheart varieties. The planted area was surrounded by a substantial windbreak of hop lewing on 6ft. wire netting, and no wind damage was observed.

Warning system

The warning system was extended to cover the Plant Physiology Department's glasshouse and field laboratory.

Reserve land

The 41 acres of reserve land were sown to a permanent ley in April. It had been hoped to graze the land in the autumn, but owing to the abnormally high rainfall this proved impossible. Fencing started in December, and it is expected that grazing will begin in March 1961.

Windbreaks

Some 2,500 *Cupressocyparis leylandii* and 350 *Quercus ilex* were propagated for spring planting in 1961, together with additional *Pinus radiata* and *Escallonia* 'Crimson Spire'.

II. GENERAL REVIEW OF RESEARCH WORK

1. PLANT BREEDING

by

L. A. DARBY

Tomato

Plant-habit

Three or four cycles have now been completed in the back-cross programmes by which compact plant habit is being incorporated in several existing commercial varieties. The differences in leaf, truss and fruit characteristics between the original varieties are readily seen in the corresponding compact-habit forms. The programmes are being continued for further back-cross cycles, but bulked-up seed has been produced so that the cropping potential of the new compact-habit forms can be assessed in replicated yield trials. Crosses have also been made between these compact-habit forms so that certain compact-habit F_1 hybrids can be included in the 1961 trials.

During the course of these back-cross programmes new genotypes have been selected by the pure line method which combine compact habit with fruit of a quality which is superior to that produced by the variety 'Baby Lea', the source of the compact-habit character. These lines were developed in order to gain experience in managing plants with compact habit, and also to ascertain whether or not such types would be acceptable to the industry. For the past two or three years this material has been grown at this Institute, at the Experimental Horticulture Stations of the National Agricultural Advisory Service and by certain growers. The families derived from the original cross between 'Baby Lea' and 'E.S.5' have aroused considerable interest among 'Potentate' growers because the plants combine good quality fruit with restricted vegetative growth. In view of the generally favourable comments about this material, which has now been inbred to the F_3 or F_4 generation, and also in view of the fact that the back-cross and F_1 hybrid material described above will soon be going into trials, it was decided that the pure-line selections should be released for wider testing by commercial growers.

The material has been numbered GCR2-25, and the distribution of seed was organised through the Institute's Subscription Scheme and also through the Tomato and Cucumber Marketing Board. All the varieties have compact habit, which gives shorter leaves, with trusses and leaves closer together, and with more restricted root development. This is typical of the variety 'Baby Lea', though the GCR varieties are stronger growing because of the influence of the other parent 'E.S.5'. Several lines were selected in an attempt to fix varieties which are different in fruit size. Some varieties give smaller fruit, of which a high proportion are round and uniformly coloured. Others, which usually give a heavier crop, have larger fruit, and this inevitably leads to some reduction in fruit quality. In distributing the material it has been the aim to give each grower, within the limits of seed supply, two contrasting varieties so that their relative merits can be compared. Participants in the trials are being asked to complete a brief questionnaire at the end of the season in order to facilitate the assessment of the material.

The GCR varieties do not represent any great break-through in the search for improved fruit quality. In fact, the quality is akin to that already obtainable from certain existing strong-growing varieties. What the new varieties do is to make this better fruit quality available to a larger number of growers by combining it with a more restricted vegetative growth to give the type of plant that these growers like to manage. They do not incorporate any disease-resistance factors, nor do they carry the even-ripening characteristic of the Stonor varieties. Accordingly, like most varieties, they are susceptible to green-back under certain conditions.

As mentioned previously, the new varieties have been bred as possible replacements for 'Potentate', 'Baby Lea' and similar types, and, therefore, they are most suited to the conditions and culture reserved for those types. It is strongly recommended that these GCR varieties should only be grown in steam-sterilised soils, and it is urged that any grower who does not plant fairly early, in a heated house, on steamed soil, should restrict his trial to a small number of plants. Given the right conditions, and coupling them with adequate culture, these compact-habit varieties are capable of maintaining growth for the full season, even should they become infected with mosaic virus. All the plants are green-stemmed and do not develop the usual purple pigment when grown hard. For growers who judge the condition of their plants by their colour it has been suggested that a few 'Potentate' plants should be included in the house to assist in making decisions on cultural adjustments.

Uniform ripening

The breeding programmes to transfer the recessive allele for uniform ripening into the varieties 'Ailsa Craig' and 'Potentate' have now completed three back-cross cycles. The two resulting families are uniform in appearance, and plants have the habit, truss type, fruit size and shape of the recurrent parent plus the freedom from green-back which was derived from 'Moneymaker'. Throughout the breeding programme plants have always been grown in pots, but seed has now been bulked up so that yield trials of border grown plants can be conducted in 1961. The back-cross programme is also being continued through a fourth cycle. Similar programmes involving other varieties are at earlier stages.

Trials by selected growers

It is of great assistance to have new material tested by growers as early as possible in any breeding programme, and this is especially so with tomatoes when a small fault may detract very considerably from the value of a variety. The National Agricultural Advisory Service and corresponding organisations in Scotland, Ireland and Guernsey have co-operated extensively in organising a panel of growers who are prepared to test new material and to report on its behaviour and characteristics. In order to ensure wide coverage growers from all regions and with contrasting facilities and cultural methods have been invited to participate in the scheme. Our thanks are due to the N.A.A.S. and other organisations, and also to the co-operating growers.

Three selections have been offered for trial in 1961 :

- B920 A compact-habit form of 'Moneymaker'. This is a green-stem variety with growth similar to 'Baby Lea', but identical with 'Moneymaker' in other characters.
- B739 A form of 'Potentate' free from green-back. In plant habit, truss type, fruit size, shape and susceptibility to blotchy ripening it is identical with 'Potentate'.
- B738 A form of 'Ailsa Craig' free from green-back. In plant habit, truss type and fruit quality it is identical with 'Ailsa Craig'.

All varieties remain free from green-back, but there are marked varietal differences in plant habit.

Disease resistance

With the appointment of Mr. A. C. Hastie in October, the tomato breeding programmes are being extended to include disease resistance, and the control of Tomato Mosaic Virus, *Cladosporium fulvum* and *Botrytis* is to be investigated. Wild and cultivated tomato species and varieties are being collected so that they can be screened for any useful genotypes. We are indebted to the John Innes Institute who have passed on certain *Cladosporium*-resistant stocks for further development.

Grafted plants

Mr. J. W. M. Smith conducted a small trial on grafting techniques in order to prepare for further work in 1961. Seventy-five per cent of the grafts were successful when both stock and scion seedlings were pricked off into the same pot and the grafting operations done at an early stage. Fifty-five per cent were successful when the seedlings were pricked off into separate pots and the graft made when the two plants were planted out. Both methods gave satisfactory scion growth.

Inter-plant competition

In trials under glass with many treatments it is rarely possible to use plots with large numbers of plants or to employ plot guards. When all treatments give plants with approximately the same vegetative growth this may not influence results, but if there are marked differences in plant stature or root spread the treatment differences may be exaggerated or obscured. Two trials were conducted to ascertain how serious inter-plant competition may be when small plots of plants with contrasting vegetative habit are grown next to each other.

Trial 1

<i>Sown</i>	1st December, 1959.
<i>Planted</i>	20th February, 1960.
<i>First harvest</i>	21st April, 1960.
<i>Crop cleared</i>	8th August, 1960.
<i>Varieties</i>	T = tall spreading habit — 'Ailsa Craig'. I = intermediate habit — 'Potentate'.

Layout

The plant rows ran north/south, but the plots (1 × 4 plants) ran east/west. The row of plants to the north and south of the plot were either the same variety as in the plot or the contrasting variety, e.g. :

<i>Plot code</i>	<i>Plot layout</i>
T I T	T T T T I I I I — recorded plants T T T T

In this plot it might be expected that 'Potentate', with its intermediate habit, would suffer in competition with the tall spreading 'Ailsa Craig'.

Thus there were four possible types of plot :

T T T I T I T I T I I I

and there were eight replicates of each plot in the experimental design.

Results

<i>Plot code</i>	<i>Yield in first 4 weeks</i> (lb./plant)	<i>Total yield</i> (lb./plant)
T T T	1.4	9.1
I T I	1.4	10.6
T I T	1.3	8.1
I I I	1.3	10.0

Trial 2

<i>Sown</i>	15th February, 1960.
<i>Planted</i>	6th April, 1960.
<i>First harvest</i>	14th June, 1960.
<i>Crop cleared</i>	25th October, 1960.
<i>Varieties</i>	I = intermediate habit—'Potentate'. C = compact habit —B641.

Layout

The experimental design and layout were similar to those in trial 1, with four plot types, four plants per plot and eight replicates.

Results

<i>Plot code</i>	<i>Yield in first 4 weeks</i> (lb./plant)	<i>Total yield</i> (lb./plant)
I I I	3.8	13.0
C I C	4.0	13.8
I C I	4.0	12.5
C C C	4.1	12.8

The data have not yet undergone statistical analysis, but although the differences are small the trends are as expected. There was very little effect on the first four weeks' yield, but in both trials the total crop from all varieties was influenced by the relative vegetative vigour of adjacent plants. For example, in trial 1 the tall spreading 'Ailsa Craig' (T) suppressed the yield of 'Potentate' (I) by 1.9lb. By contrast, in trial 2 the plots CIC gave 0.8lb. more fruit than the plots I I I. In the former the 'Potentate', with its intermediate habit, had less competition from the compact-habit variety than it did from other 'Potentate' plants.

Lettuce

In the 1959/60 winter season F_3 families derived from crosses of 'Cheshunt 5B' with paler-coloured varieties were grown at the Institute and at Fairfield Experimental Horticulture Station. Further selections were made and F_4 seed produced.

With a view to cleaning up the commercial stocks of 'Cheshunt 5B' which are often rather variable, single-plant selections were again made. After only two generations the selected lines appear to be more uniform than the commercial stocks.

Cucumber

One replicated trial was conducted to test the effects of inbreeding on the yield and fruit quality of the two varieties 'Butcher's Disease Resister' and 'Telegraph', and to examine the F_1 hybrids between these varieties when produced from outbred and inbred parents.

Further selections and back-crosses were made in the programme which aims to shorten the neck length on fruit of 'Butcher's Disease Resister'.

2. PLANT PHYSIOLOGY

by

E. R. LEONARD

A major structural alteration to the special purpose glasshouse was effected early in the year when a complete new ridge member and roof ventilator top and bottom rails were installed by the glasshouse contractors, as had been arranged in the previous year.

Trouble has again been experienced with the ventilator-actuating motors and one new, lower horse-power, non-commutator motor was obtained in October and awaits installation by the ventilation contractors. The recorder-controller, on loan in 1959, was purchased after prolonged testing and is in use, but the temporary relays and wiring require to be made permanent.

The alarm system was extended to the glasshouse to give warning of unduly low temperature and to the underground laboratory to give warning of flooding, which still exists as a hazard with the present arrangement of the calorifier, expansion tank and static head pipe. Warning lamps indicate the source of the alarm.

An improvement in propagating conditions has been achieved in the northernmost east-west glasshouse (No. 1) by temporarily raising the benches during the winter months to bring the seedlings out of the shadow of the propagatinghouse to the south. Germinating frames heated by thermostatted electric cable have been used in the corridor of the propagating block.

Long-needed additional space has been allocated in the ground floor of the annexe to the laboratory block. This has been sub-divided to provide a glass-blowing room, an instrumentation room pressurised with filtered air and thermostatted for testing recording instruments and standardising their sensing elements, and a preparation room for the construction and testing of equipment used in the Department's work. It is hoped that this room can be equipped and provided with the necessary tools during 1961. With the assistance of the Instrument Technician, appointed towards the end of the year, these facilities should greatly implement the programme of control and recording of the environment.

Soil moisture tension control and seedling growth (H. R. B. Hack).

A series of experiments was carried out on the effect of soil moisture tension on the rate of germination and emergence of seedling tomatoes. The tension was maintained constant at different levels by means of buried porous ceramic plates attached to water reservoirs. Seeds were also sown in seed boxes with initial watering only and with "excessive" watering on alternate days. Germination times were markedly affected by the different tensions.

Individual seedlings were also grown in glass-sided containers filled with compost containing a number of porous ceramic cells arranged radially from the plant and attached to water reservoirs at a lower level. Growth of tops and roots of duplicate plants were studied at four contrasted levels of soil moisture tension, and observations of the environment were made with multi-point recorders.

In the lower range of tension, near field-capacity, small differences in tension produced considerable effects on plant growth, but there were marked differences between replicates at the higher tensions, which imply interaction with other factors. These are not at present explicable.

A single plant was grown to the stage at which soil moisture tension control by this method was no longer possible with the size of container and number of ceramic cells used.

Environmental observations (H. R. B. Hack).

Additional observations on plant and soil temperatures have been made in 1960 in connection with experiments on soil moisture tension control.

With a multi-point potentiometer recorder a large number of observations are rapidly collected and the extraction of the data is a slow process. Unfortunately delivery of the modified recorder to convert readings to punched tape for evaluation by the Rothamsted computer has been delayed and no progress has been possible with this project. Meanwhile extraction of data from the strip sheet charts by visual means has been continued intermittently as assistance has been available.

3. CHEMISTRY

by

G. W. WINSOR

The work of the Chemistry Department has been concerned primarily with the nutrition of glasshouse crops and with the composition and biochemistry of tomato fruit.

On the transfer of Mr. P. B. Flegg and Miss I. I. Warman to the Horticulture Department in October, 1960, studies on mushroom culture were discontinued in this Department. Investigation of sand/peat composts was also terminated at the expiry of Mr. P. J. Sutton's post-graduate scholarship, but further investigations have been started in the Horticulture Department. On his return from British Guiana, Mr. J. H. L. Messing became responsible for the continuation of existing studies on manganese toxicity in glasshouse crops, leaving Mr. D. M. Massey free to devote his full attention to soil salinity problems.

Re-allocation of laboratories inevitably caused some interference with experimental work during the second half of the year, but all laboratories should become fully functional early in 1961.

Nutritional trials with glasshouse crops (G. W. Winsor and M. I. E. Long).

The main nutritional experiment with tomatoes was continued in Block B, and the special investigation of magnesium deficiency originally occupying houses D1 and D2 was continued for a final year in house D1 only. The experiment on potash/nitrogen ratio in liquid feeds, which occupied house C4 from 1957 to 1959, was written up for publication; this experiment was replaced in 1960 by a new project in which alternative sources of nitrogen for liquid feeds are compared.

Two experiments on the nutrition of winter lettuce were concluded in Block B, before planting the tomato crop, and further studies were commenced in the autumn.

The first of a series of nutritional studies with carnations was terminated in April, and the second experiment commenced in May.

Close contact was maintained with bulb nutrition studies in sand culture at the Kirton Experimental Husbandry Farm in Lincolnshire, and some analytical work was carried out in this connection.

The basic scheme of grading tomato fruit from the nutritional trials, given in the Annual Report for 1959 (p.30), was again used. The unevenly ripened fruit was also sub-classified into categories NUC/A-Z as approved by the A.I.C. Glasshouse Working Party. It was found desirable to sub-divide category NUC/Z as "mild" or "severe".

3² × 2³ factorial nutritional trial with tomatoes (Block B)

This long-term experiment, designed to study the main effects and interactions of four macro-nutrients, each at two levels of liming, was continued on the pattern established in the two preceding years. The plants were set out in the borders on 5th March, the variety being 'Potentate'. The soil was not steamed before the 1960 crop, and growth was far less vigorous than in the preceding season.

Soil samples were taken for analysis from all 72 plots in March, May and early October. The analytical work has not yet been completed, but mean values at the first date of sampling were as follows:—

<i>Potassium levels</i>	<i>K1</i>	<i>K2</i>	<i>K3</i>
"Available" potash (K_2O)	0.006%	0.042%	0.091%
<i>Phosphorus levels</i>	<i>P1</i>	<i>P2</i>	
"Available" phosphate (P_2O_5)	0.007%	0.066%	
<i>Nitrogen levels</i>	<i>N1</i>	<i>N2</i>	<i>N3</i>
Nitrate-nitrogen	11 p.p.m.	34 p.p.m.	82 p.p.m.
<i>Liming levels</i>	<i>Ca1</i>	<i>Ca2</i>	
pH	6.4	7.4	
<i>Range of pC values</i>		2.6—3.7	
(2.5 : 1 aqueous suspensions)			

These mean values for soil samples taken shortly after planting give some indication of the general levels attained; the full pattern of seasonal trends and nutrient interaction is, of course, far more complex. In the unlimed (Ca1) plots, for example, the pH is primarily controlled by the levels of nitrogen, the mean pH values at Ca1N1, Ca1N2 and Ca1N3 being 7.0, 6.4 and 5.1 respectively during May.

Data for yields, grading and heights of plants (in June) have been sent to Rothamsted for statistical computation. In this third year of the trial the combination of unsteamed soil and relatively acute nutrient deficiency in the N1 and K1 levels of treatment markedly reduced crop yields. Considerable losses of plants resulted by mid-season, these being closely associated with nitrogen and potash deficiencies although such plants finally succumbed to *Botrytis*. The yields per plant originally set out in the plots, uncorrected for plants lost in view of the relation to manurial treatments, ranged from 10.1 lb. at high levels of nitrogen, phosphate and potash to 2.5 lb. in a potash-deficient plot.

Averaged over all treatment combinations other than those showing acute potassium deficiency (K1) the mean response of yield (per plant) to nitrogen level was as follows:—

<i>N1</i>	<i>N2</i>	<i>N3</i>
4.05 lb.	6.56 lb.	7.27 lb.

The corresponding data for levels of potassium, omitting combinations including N1, were:—

<i>K1</i>	<i>K2</i>	<i>K3</i>
3.24 lb.	7.03 lb.	6.79 lb.

Magnesium sulphate as a soil treatment depressed yields where nitrogen or potash were seriously deficient, but not when adequate levels of the latter nutrients were present.

Phosphate increased yields by 0.4 lb. per plant where nitrogen and potash were adequate, but was without effect on yields where either of the latter nutrients limited growth.

Liming had no effect where nitrogen or potash were limiting factors (N1 or K1), but reduced yields by 21% on average where adequate levels of nitrogen and potash were maintained.

The most striking results were those for fruit quality in relation to potassium levels. Data for the percentage of unevenly ripened fruit (by weight), and for sub-grades NUC/A, C, D and Z (by number) were as follows, averaged over all treatment combinations:—

	<i>K1</i>	<i>K2</i>	<i>K3</i>
% Unevenly ripened fruit	80.2	22.0	14.0
% NUC/A ("Greenback")	16.9	7.4	4.9
% NUC/C (Green "blotch")	21.3	5.9	3.5
% NUC/D ("Waxy")	3.4	0.5	0.1
% NUC/Z (severe forms only)	25.4	1.6	0.7

Two complete sets of leaf samples were taken for chemical analysis during the season, and these are now being examined. One set of 72 fruit samples was also taken for analysis; the results, summarized in a later section, illustrate the importance of plant nutrition in achieving high fruit quality.

Comparison of four sources of nitrogen in liquid feeds (House C4)

A new experiment with trickle irrigation equipment was started during the year, in which urea, ammonium sulphate, ammonium nitrate and a mixture of potassium and sodium nitrates were compared as sources of nitrogen for the tomato crop. These four treatments represent the supply of (1) organic nitrogen, (2) ammonium-nitrogen, (3) ammonium and nitrate-nitrogen and (4) nitrate-nitrogen alone. Owing to microbiological changes in the soil these treatments do not, of course, ensure an entirely ammonium or nitrate supply for the plants, nor can the effects be entirely dissociated from consequent pH changes or the presence of other ions (e.g., sulphate or sodium).

The plants (variety: 'Potentate') were set out in the borders on 26th February, there being six replications in all; the layout was planned to permit statistical evaluation of residual effects from the preceding studies of potash/nitrogen ratio in four of the replications. The potash/nitrogen ratio (K_2O/N) of the nutrient solutions was initially 2.25 in all treatments, but was later reduced to 2.0.

Magnesium deficiency symptoms were closely associated with the residual effects of the preceding experiment, increasing in severity with the potassium levels of 1957-9. Manganese toxicity symptoms were most readily apparent where ammonium sulphate was applied, probably owing to increased acidity.

Soil samples were taken for the estimation of pH and salinity. Leaf samples were analysed for manganese content, and fruit samples were included in the studies of tomato composition.

The total yields of ripened fruit were fairly high:—

Urea	12.9 lb. per plant
Ammonium sulphate	12.9 " " "
Ammonium nitrate	13.2 " " "
Potassium and sodium nitrate	12.0 " " "
Least significant difference at $P=0.01$	0.82

Thus the nutrient solution supplying all the nitrogen as nitrate gave a significantly lower yield than the other three treatments. This treatment also gave the highest percentage of irregularly coloured fruit. The highest proportion of high quality fruit was given by ammonium sulphate. The experiment thus gave a significant response in terms of both yield and quality in the first year, and will be repeated in 1961.

Magnesium in the nutrition of glasshouse tomatoes (House D1)

The experiment on magnesium deficiency and magnesium-potassium interaction was continued for a fourth and final season. The treatments and layout were described in the Annual Reports for 1957-1959.

Symptoms of magnesium deficiency occurred in the foliage wherever magnesium was not supplied, and both soil and spray treatments were effective in controlling the disorder. Samples of soil were taken for examination of the ratio of "available" potassium and magnesium in plots receiving the various treatments. Periodic leaf samples were collected in order to study changes in magnesium content of foliage from the different treatments. Samples of uniformly

coloured fruit were taken on eleven occasions throughout the year for studies of tomato fruit composition; the results are described in a later section.

The effects of the manurial treatments on yields and grading of fruit were as follows:—

Treatment	Potash	Magnesium	Yield (lb./plant)		Grades A + B (%)	
			'Potentate'	'Immuna'	'Potentate'	'Immuna'
A	"Low"	None added	8.8	9.9	34	49
B	"	Soil application	9.1	10.3	55	58
C	"	Foliar spray	8.9	10.7	45	57
D	"High"	None added	9.6	10.7	77	86
E	"	Soil application	10.1	10.7	78	85
F	"	Foliar spray	10.0	10.6	74	84

The full yield and grading results have been sent to Rothamsted for statistical computation. It is at once apparent, however, that the very marked response in yield from treatments supplying magnesium at the higher level of potash during 1959 has not been repeated in 1960. Comparison of treatments D, E and F for variety 'Potentate' shows a gain of 0.5 lb. per plant from magnesium sulphate applied to the soil, and of 0.4 lb. from foliar sprays; no corresponding responses were found for variety 'Immuna' despite its greater susceptibility to chlorosis. Some improvement in fruit quality resulted from both treatments supplying magnesium at the lower level of potash. The factor having the greatest effect on fruit quality was again the rate of application of potash.

When the analytical studies and statistical examination of the data have been completed, the combined results for the four years of this experiment will be prepared for publication. It appears that the tomato plant will tolerate a certain degree of magnesium deficiency without significant loss in yield, but that nevertheless under certain conditions, as in this experiment during 1959, a major loss of crop can result from failure to correct this deficiency.

Nutritional trial with carnations (House E2)

The first of a series of nutritional studies with glasshouse carnations, started in 1958, was terminated in April 1960. The design and layout of this experiment were described in the Annual Reports for 1958 and 1959, together with the interim results. The data for crop yields and for chemical composition of the foliage have now been analysed statistically, and a full account of the experiment will be prepared for publication in due course. One interesting result from the trial is shown in the following data for the percentages of blooms with split calyces as influenced by the levels of nitrogen applied:—

Variety	N1	N2	N3
'Improved William Sim'	45.1%	31.4%	27.3%
'Saugus White'	15.4%	8.6%	6.9%

'William Sim' was far more prone to splitting of the calyx than 'Saugus White', but in both varieties the proportion of "splits" decreased with increasing nitrogen level.

The second experiment in this series was started in May 1960. The concrete beds were further sub-divided to give a total of 96 plots, each carrying two varieties ('William Sim' and 'Pink Sim'). The treatments include four levels of nitrogen and three levels of potash applied in solution via trickle irrigation equipment. These treatments are superimposed on four levels of phosphate and two levels of lime incorporated in the compost, giving a total of $4 \times 4 \times 3 \times 2 = 96$ treatments in factorial combination. The compost is a mixture of steamed loam with peat (15%) and grit (5%). The irrigation system has been fitted with additional plastic rods to

improve the distribution of water and nutrients. The main grading scheme for blooms is as in the preceding experiment; each bloom is classified as "spilt" or "ndt split" and also as of first or second quality (ignoring "splitting").

The plants in this experiment were set out in the plots as rooted cuttings, whereas in the preceding trial the plants were from "60"-pots. This has resulted in an earlier response to the nutritional treatments. The effect of phosphate-deficiency became apparent within a few weeks of planting, and distortion of the young shoots ("curly top") developed in the first winter where either nitrogen or phosphate was at a low level in the soil; the latter effect only occurred in the second winter during the previous trial. Steaming induced less mineralization of soil nitrogen in this second trial, and an increased response to levels of added nitrogen therefore seems likely. A clear difference between the pH of the limed and unlimed plots was also established, unlike the previous trial in which the acidity of the superphosphate tended to control the soil pH even where heavy dressings of fine calcium carbonate had been incorporated; this difficulty was overcome by the inclusion of some hydrated lime with the carbonate in the second experiment.

3² × 2³ factorial nutritional trials with lettuce (Block B)

Studies on the nutrition of winter lettuce (variety: 'Cheshunt 5B'), commenced in the autumn of 1959 and briefly described in the Annual Report for that year, were continued with a second crop (variety: 'Cheshunt Early Giant'), planted in late December, 1959. This second planting did not reach maturity before the houses were required for the tomato crop of 1960, but much information was obtained on the growth of the plants in relation to soil nutrient levels.

The average weight of the lettuce plants when harvested (21st January) was highest at the intermediate level of nitrogen, the higher level of phosphate and the intermediate and highest levels of potash. A significant interaction was found between nitrogen and phosphate levels in the soil, high nitrogen having an adverse effect at low phosphate levels.

Analytical work on the first of the two lettuce crops has now been completed, and has given interesting information on manganese uptake and toxicity symptoms in relation to manurial treatment and soil pH.

This investigation was continued with a third crop of lettuce (variety: 'Cheshunt 5B') planted out in early November 1960. The plants are again showing very marked responses to nutrient levels in the soil, but no quantitative data are yet available.

Factorial nutritional trial with early outdoor chrysanthemums

A factorial study on the nutrition of this crop was commenced during 1960 in co-operation with the Horticulture Department. The experimental treatments include three levels of dung, nitrogen, phosphate and potash in factorial combination, making a total of 81 plots. The variety grown was 'Sweetheart'.

The main responses in 1960 were to nitrogen and dung. The full results for flower-production are at present being computed statistically at Rothamsted. Soil and leaf samples are now being analysed, and a joint report with the Horticulture Department will be prepared at a later date.

Manganese toxicity (J. H. L. Messing).

Instances of manganese toxicity have again occurred in certain trial glasshouses where the soil has been steam sterilized, and also in potting composts prepared with steamed loam from the site of the Institute.

In addition to studies on the manganese content of crops grown in the nutritional trials, a further series of experiments dealing specifically with the problem of manganese toxicity has now been initiated. Previous experience showed that the lettuce plant is very susceptible to this disorder, and it was accordingly chosen as the test plant for pot experiments. The potting mixture consisted of steamed loam and peat (the latter 20% by volume).

The first experiment was designed to study the effects of lime and phosphate in factorial combination, there being 18 treatments and 10 replications. Unfortunately the amounts of manganese released on steaming, though approaching the toxic level for lettuce, were insufficient in this instance to produce definite toxicity symptoms. Much information was nevertheless obtained on the effects of various treatments upon manganese levels in both soil and plants.

Liming decreased the content of water-soluble manganese in the soil without affecting the exchangeable or easily reducible categories of this element. The manganese content of the lettuce plants decreased with increasing levels of lime. Heavy dressings of phosphate, applied as finely ground triple superphosphate, increased the water-soluble and exchangeable manganese in the soil, decreased the easily reducible manganese, and increased the content of manganese in the lettuce plants.

The various combinations of lime and phosphate produced a wide range of pH values in the treated soils. The pH at the end of the experiment was significantly correlated with water-soluble manganese in the soil ($r = -0.72$), with exchangeable manganese ($r = -0.57$), and with the content of manganese in the lettuce plants ($r = -0.89$). The effects of lime and phosphate appeared to be due primarily to changes in soil pH.

A review of the literature suggested that chelating agents, iron compounds and molybdenum salts may have an appreciable effect on manganese toxicity, and preliminary trials were accordingly undertaken. Some reduction in the manganese content of lettuce plants was achieved with the sodium salt of ethylenediaminetetra-acetic acid and with the chelated iron compound, but at the higher concentrations a considerable check to growth resulted. Small amounts of ammonium molybdate also reduced the manganese content of the plants.

Eleven varieties of lettuce were included in a trial on varietal susceptibility to manganese toxicity. Again the results were limited by the absence of visual symptoms of toxicity, but chemical analysis revealed marked differences in the manganese content of the lettuce. Thus two Cheshunt varieties ('Early Giant' and '5B') showed the highest manganese content (479 and 439 p.p.m. Mn in the oven-dried tissue), whereas 'May Queen' and 'Golden Queen' gave the lowest values (292 and 255 p.p.m. respectively).

Soils from a number of different sites at the Institute have since been examined with regard to levels of available manganese when steamed. Soil taken from near the outdoor chrysanthemum trial was found to give a high release of manganese, and is now being used for the continuation of this investigation.

Soil salinity studies (D. M. Massey and G. W. Winsor).

From previous studies it was concluded that the ratio of added water to soil used in the preparation of soil extracts or suspensions for measurements of electrical conductivity should be kept to a minimum; complications arising from the presence of sparingly soluble salts can be minimized in this way. In view of the experimental difficulties involved with displaced soil solutions, the soil saturation paste extract appeared to represent the lowest water:soil ratio likely to be used for routine diagnostic purposes, and even this procedure is relatively slow and tedious to operate.

The moisture content of a soil paste, known as the "saturation percentage", varies with the physical characteristics of the soil. Filtrates from such pastes are thus prepared at a water: soil ratio dependent on the water-holding properties of the soil rather than at a constant water: soil ratio. The saturation paste procedure accordingly appears to include some degree of compensation for differences in soil texture; for example, soils with a high water-holding capacity in the field would tend to have high "saturation percentages" in this test. Differences in soil texture might also be expected to influence the results obtained from direct conductivity measurements with robust electrodes in contact with the soil pastes, since the proportion of non-conducting solid material between the electrodes would vary with the physical nature of the soil or compost.

Preliminary attention was given during 1960 to studies on the effect of different water-holding characteristics upon the relation between growth and salinity. Potting mixtures having different "saturation percentages" were prepared by adding varying proportions of sand or peat to loam from the Institute site. The test plants were lettuce, grown in "32"-pots. Up to ten different levels of fertilizer have been applied in factorial combination with the various soil mixtures, the object being to establish the regression of plant weight on soil salinity for each soil/sand or soil/peat mixture. Soil salinity was estimated in filtrates from the saturation pastes, by direct measurements with carbon electrodes in the saturation pastes themselves, and in suspensions prepared at water: soil ratios of 1:1, 2.5:1 and 5:1.

One preliminary and two larger experiments have so far been conducted in the glasshouse, but the salinity determinations have not yet been completed and much statistical work will be necessary before valid conclusions can be drawn.

The composition of tomato fruit (G. W. Winsor and J. N. Davies).

During 1960 the routine analytical procedures developed for examining large numbers of fruit samples have been used to investigate the following:—

- (a) The composition of tomato fruit in relation to manurial treatment.
- (b) The composition of fruit from virus-infected and uninfected plants.
- (c) Comparison of the fruit of different varieties.
- (d) The effect of environmental factors on the composition of fruit of two varieties.
- (e) The effects of leaf and fruit restriction on fruit composition.
- (f) Comparison of hormone-set and naturally pollinated fruit.

Extensive data have now been accumulated from these and previous studies, showing the way in which the main taste constituents of the tomato, particularly the sugars and acids, are influenced by nutrition, variety, environment and other factors.

Further data have been obtained confirming the close relation existing between the refractive index of the expressed sap and the total soluble solids as determined by oven-drying. The results collected over three years are now undergoing final statistical analysis. A comparison of normal and vacuum-oven drying for the determination of total soluble solids has also been made.

Seasonal trends in the composition of the expressed sap have again been noted in many of the investigations. In general the content of total solids and sugars increased to a maximum in late July or early August. The titratable acidity reached its maximum a fortnight or so earlier and decreased subsequently.

The composition of tomato fruit (variety: 'Potentate') from the $3^2 \times 2^3$ factorial nutritional trial (Block B)

Studies on the composition of fruit from this nutritional trial, which has been referred to in another section of this Report, have been continued and extended in 1960. The large numbers of samples involved have again necessitated the use of the hydraulic press and semi-micro analytical procedures. Samples of the best quality fruit available were collected in July from each of the 72 experimental plots. The titratable acidity, total acidity, refractive index, specific conductivity, and potassium and sodium contents of the expressed sap were determined on every sample. Determinations of sugars and dry matter content were also made on a limited number of samples. In August a further set of samples was taken from the 18 unlimed plots (Ca1) which received dressings of magnesium sulphate (Mg2).

Statistical analysis of the data for the full set of samples collected in July confirms the main trends observed in 1959. For example, potash applied at the "medium" and "high" levels (K2 and K3) increased the titratable acidity of the fruit as compared with the "low" (K1) level, the effect being significant at $P=0.001$. A similar effect was noted for the total acidity of the fruit. Significant increases in the titratable and total acidity of the expressed sap also resulted from increasing applications of nitrogen.

The potash content and specific conductivity of the expressed sap were significantly increased by increasing applications of potash and by the addition of phosphate. A significant interaction was found between the effects of nitrogen and potash on both the potash content and the specific conductivity of the sap. Mean values for the specific conductivity of the expressed sap, measured at 20°C. and expressed in millimhos, were as follows:—

<i>Potash levels</i>	<i>Nitrogen levels</i>			<i>Potash level means</i>
	<i>N1</i>	<i>N2</i>	<i>N3</i>	
<i>K1</i>	4.08	3.68	3.83	3.86
<i>K2</i>	6.24	6.17	6.24	6.22
<i>K3</i>	6.55	6.69	7.17	6.80
<i>Nitrogen level means</i>	5.62	5.52	5.75	

The results show that, at the lowest level of potash (K1), the higher applications of nitrogen reduced the specific conductivity of the sap, whereas at the "high" potash level (K3) there was an increase in specific conductivity with increasing nitrogen levels. Similar trends were, in general, observed in the potash content of the expressed sap.

The sodium content of tomato fruit is very much less than the potash content, comprising only a few per cent of the total cations present, and in this trial was significantly reduced by the application of potash.

The composition of virus-infected tomato fruit

An investigation of the effects of virus infection on the growth and cropping of two varieties of tomato ('Potentate' and 'Moneymaker'), conducted by the Virology Department, gave an opportunity to compare the composition of tomato fruit from virus-infected and virus-free plants. Samples of good quality fruit of both varieties were obtained on eight occasions between May and August from uninfected plants, and from plants infected early (on 3rd March) and in mid-season (on 14th April). On the last four sampling dates, in July and August, additional fruit samples were obtained from plants infected later in the season (on 31st May).

Virus infection of the plants had an effect on some aspects of the composition of the fruit of variety 'Moneymaker', as shown by the following mean values :—

	<i>Uninfected</i>	<i>Infected</i> (3rd March)	<i>Infected</i> (14th April)	<i>L.S.D.*</i>
Sugars in the expressed sap (g./100 ml.)	2.38	2.62	2.62	0.15
Total solids (g./100 ml.)	3.90	4.13	4.27	0.18
Titrateable acidity (milliequivalents per 100 ml.)	6.60	6.77	6.74	0.10

*Least significant difference at $P = 0.05$.

Reducing sugars and total solids in the expressed sap of the fruit of variety 'Moneymaker' were significantly increased by virus infection, as also was the titrateable acidity. A similar effect was noted with variety 'Potentate' with regard to the reducing sugars and sap solids, but with this variety a decrease in titrateable acidity was observed which was not however statistically significant.

The reason for the increased content of sugars and total solids in the uniformly coloured and regularly shaped fruit from virus-infected plants is still uncertain. Both the total yields per plant and the proportion of high grade fruit were, of course, reduced by virus infection. This reduction in yield may itself account for the small but significant increase observed in the content of sugars and other constituents.

The effect of some environmental factors on fruit composition

A study has been made of the effects of temperature, shading and watering on the composition of the fruit of two varieties of tomato ('Potentate' and 'Ware Cross'). The fruit used in this investigation was kindly supplied by the Director of the Lee Valley Experimental Horticulture Station from an experiment sponsored by the Horticulture Department.

Statistical analysis of the limited data so far obtained has shown that the content of sugars and total solids in the expressed sap of both varieties was significantly decreased by shading, whereas the temperature and watering treatments had no significant effect. The titrateable acidity of the fruit juices was not significantly influenced by either watering or shading, but was significantly reduced at the higher temperature. In addition, significant interactions between temperature and shading treatments were noted for the sugar content, total solids and titrateable acidity of the expressed sap of the fruit of both varieties.

The results show that much interesting information can be gained by the application of analytical procedures to environmental studies of this type. The main difficulty encountered so far has been in the transport of fruit samples for analysis without delay or damage. New arrangements to overcome this difficulty are proposed for 1961.

The effect of leaf and fruit restriction on the composition of tomato fruit

In an earlier investigation (Annual Report for 1957, pp. 53–66) it was shown that reducing the number of leaves on a tomato plant markedly affected the composition of the fruit. During 1960 a further experiment was conducted in which varying degrees of defoliation were combined

with the retention of different numbers of fruit per truss. Three defoliation treatments were included, these being :—

- (a) All leaves retained.
- (b) Two leaves retained between successive trusses.
- (c) One leaf retained between successive trusses.

These three treatments were arranged in factorial combination with two numbers of fruit per truss :—

- (i) All fruit retained up to a maximum of eight fruit per truss.
- (ii) Two fruit retained per truss

The fruit used in this investigation was of the best quality available from each of five successive trusses on pot-grown plants of the variety 'Potentate'. The analytical results include data for total solids, sugars, titratable and total acidities, potassium and sodium content, and the refractive index of the expressed sap.

As an example of the results obtained, the mean data for total solids (g./100 ml.) in the expressed sap were as follows :—

<i>No. of fruit per truss</i>	<i>No. of leaves retained per truss</i>			<i>Mean</i>
	<i>All</i>	<i>2</i>	<i>1</i>	
8	4.86	4.58	4.06	4.50
2	5.29	4.95	4.57	4.94
<i>Mean</i>	5.08	4.76	4.32	—

The total solids content of the expressed sap was markedly reduced by partial defoliation, whereas limiting the number of fruit per truss resulted in an increase. Both effects were significant at $P=0.001$. Similar trends were noted for the sugars and refractive index of the expressed sap, and for the dry matter content of the fruit. The acidity of the fruit was not influenced by the defoliation treatments, but reducing the number of fruit per truss resulted in an increase in both the titratable and total acidities, significant at $P=0.001$ in both cases.

The effects of manurial treatments supplying potassium and magnesium on the composition of tomato fruit of varieties 'Potentate' and 'Immuna'

Fruit of both varieties was obtained from plants receiving six different combinations of fertilizer treatment (three magnesium treatments, each at "low" and "high" levels of potash) in a nutritional trial (house D1) which has been described in an earlier section of this Report.

The effect of "high" as compared with "low" potash was to increase the mean values for the titratable acidity of the expressed sap of both varieties, the difference being significant at $P=0.001$. The mean values at "low" and "high" levels of potash were 6.2 and 7.7 milliequivalents of acid/100 ml. sap for variety 'Potentate', the corresponding values for 'Immuna' being 7.3 and 8.7 milliequivalents respectively. These differences in acidity were again reflected in the data for total solids in the sap, although in the case of 'Immuna' the increase was not statistically significant.

As in the previous years of this trial, the effects of magnesium upon fruit composition were less marked than those of potassium, but the results for titratable acidity show a highly significant interaction ($P=0.001$) between magnesium and potassium treatments. Thus at the "low" level of soil potash both foliar sprays and soil applications of magnesium sulphate

significantly increased the acidity of fruit of variety 'Potentate' ($P=0.05$), whereas at the "high" potash level there was some decrease in acidity from both magnesium treatments (though not statistically significant). The titratable acidity of fruit of variety 'Immuna' was also increased significantly by foliar sprays of magnesium sulphate at "low" potash, and decreased ($P=0.05$) by this treatment at "high" potash.

The composition of different varieties of tomato

The following seven varieties of tomato were grown in Block B for studies on the composition of different varieties of tomato :—

- | | |
|------------------|----------------|
| A. 'Potentate' | E. 'L.M.R.1' |
| B. 'Ailsa Craig' | F. 'Delicious' |
| C. 'Moneymaker' | G. 'Radio' |
| D. 'E.S.5' | |

The experimental plants occupied the guard plots adjoining the outside of the block, each variety being replicated five times. Samples of the best quality fruit obtainable from each variety were collected on eleven occasions between late May and early September for analysis of the expressed sap.

Statistical analysis of the data showed highly significant differences between varieties in titratable acidity, total solids and refractive index of the expressed sap. Mean values for titratable acidity ranged from 7.8 milliequivalents of acid/100 ml. sap for variety 'Potentate' to 10.9 for 'L.M.R.1'. It may be noted that, during similar studies in 1958 and 1959, it was also found that 'L.M.R.1' was the most acid variety, and that 'Potentate' was among the least acid varieties. Varieties 'L.M.R.1' and 'Ailsa Craig' showed the highest total solids content in the expressed sap, and 'Potentate' and 'E.S.5' the lowest, a result which was reflected in their respective refractive indices.

From these and earlier studies it is concluded that acidity is probably the most characteristic feature in the composition of fruit of different varieties grown under one set of conditions.

The effect of different sources of nitrogen in liquid feeds on the composition of tomato fruit (variety: 'Potentate')

Studies of the effect of different sources of nitrogen in liquid feeds on the growth, cropping and fruit quality of tomatoes, begun in house C4 during 1960, have been described in an earlier section of this Report. The nitrogenous compounds studied were (A) urea, (B) ammonium sulphate, (C) ammonium nitrate and (D) potassium and sodium nitrates. Samples of the best quality fruit available (grade A) from each of the four treatments were collected for analysis on eleven occasions between the middle of May and the beginning of September.

Despite significant differences in yields and visual grading, the various sources of nitrogen used in the liquid feeds had no significant effect on the titratable acidity, reducing sugar content, total solids and refractive index of juices expressed from grade A fruit. Thus the mean values for total solids ranged between 4.35 and 4.48 g./100 ml. sap, and the titratable acidity between 7.1 and 7.5 milliequivalents of acid/100 ml. sap. The potassium content of the expressed sap was not significantly influenced by the different treatments, but the sodium content of the sap of fruit from treatment D (0.67 milliequivalents Na/100 ml.) was over twice as high as that of fruit from the other three treatments (0.27—0.31 milliequivalents Na/100 ml.).

Studies of the non-volatile acids of the tomato fruit (J. N. Davies)

The principal non-volatile acids of the tomato fruit are citric and malic acids. During 1960 a study of the quantitative changes in these and other acids during the growth and ripening of tomato fruit was started, using the technique of gradient elution chromatography on anion exchange resins as outlined briefly in the Annual Report for 1959. Some attention was also given to the relative concentrations of the various acids in different varieties of tomato fruit and their relation to fruit quality.

Citric acid accounts for some 50–60% of the total acidity of good quality ripe fruit, and malic acid for between 15 and 25%. In varieties such as 'Potentate' and 'Moneymaker' the malic/citric acid ratio is about 0.5. The varieties 'L.M.R.1' and 'Delicious', on the other hand, contain a higher proportion of citric acid, resulting in a malic/citric acid ratio of about 0.25. Even lower malic/citric acid ratios of 0.15 and 0.10 have been noted in the fruit of *Lycopersicum pimpinellifolium* and the variety 'Never-ripe' respectively.

With regard to the development and ripening of tomato fruit, it would appear from the limited data so far obtained that in immature green fruit malic acid is the predominant acid. As the fruit develops, however, the concentration of malic acid falls fairly rapidly, while that of citric acid, which forms some 25% of the total acidity of fruit of about $\frac{1}{2}$ in. diameter, begins to increase. This increase in citric acid reaches a peak around the first appearance of colour in the fruit and subsequently declines, but not to the same extent as the malic acid concentration. These changes are reflected in the values obtained for the malic/citric acid ratio, this ratio decreasing progressively throughout development and ripening.

It is planned to continue these studies during 1961, and to extend them to include the effect of various nutritional factors on the non-volatile acids of the tomato fruit.

Pectic substances in tomato fruit (G. E. Hobson)

Studies on the changes in content of pectic substances and on pectin methylesterase activity during ripening have been continued with two varieties of tomato ('Potentate' and 'Immuna').

From the "mature green" stage to the fully ripe condition the total content of pectic substances, as determined by the method of McCready & McComb (1952), was found to decrease by approximately one third. A high proportion of the pectic material in the green fruit was in insoluble form, but by the time the fruit was fully coloured most of this had been transformed into soluble components. After precipitation of the bulk of the soluble pectic substances with alcohol, further analysis showed only traces of galacturonic acid and of oligouronides soluble in aqueous alcohol.

Expressed on the basis of the fresh fruit, pectin methylesterase activity increased from the mature green to the red stage of ripeness in fruit of both varieties. The greatest increase in enzyme activity was associated with the first appearance of orange colour in the fruit, and the subsequent rise in pectin methylesterase activity from the green-orange to the red stage was not statistically significant. There was more pectin methylesterase in fruit of variety 'Immuna' than in 'Potentate'.

Pectin methylesterase activity and the content of pectic substances have also been studied in "blotchy" tomatoes. Little difference was found in the total content of pectic substances in the red and the green areas of "blotchy" fruit, but the proportion of this pectic material in soluble form was higher in the red areas. Whilst the latter result is compatible with the changes found in fruit ripening normally, the total pectic content of the red areas of "blotchy" fruit was considerably higher than that of uniformly coloured red fruit of both varieties. Further-

more the proportion of this pectic material present in soluble form was lower in red areas from "blotchy" fruit than in the evenly ripened red fruit. It thus appears that even the red areas of "blotchy" fruit may be abnormal in some respects.

Pectin methylesterase activity was significantly higher in the red than in the green areas of "blotchy" fruit. There is as yet, however, no evidence to suggest that failure of the "blotchy" areas to ripen normally is due to an insufficiency of this enzyme in the tissue.

Studies on polygalacturonase, a further enzyme associated with changes in the pectic substances during ripening, have now been initiated.

Experiments have been continued on the effects of certain enzyme-inhibitors which, when injected into tomato fruit, influence the rate of ripening; a report on this work will shortly be submitted for publication.

4. STATISTICS

by

D. COOKE

Design and analysis of experiments

Assistance has been given to other research workers on the design and analysis of experiments.

Two problems, which were mentioned in last year's report as being of particular importance, are being investigated. One is that of experimentation with environmental treatments. The requirements in minimum number and size of units (which might be separate glasshouses or compartments of a large glasshouse) are being formulated in order to help in planning research installations for workers who are concerned with such experiments. One such installation, "Cathie" (for Controlled Atmosphere Temperature and Humidity Investigation Experiments), already exists for mushroom work at the Institute. A study of the results from preliminary trials with "Cathie" is proving helpful in the consideration of the general problem.

The second problem being investigated is that of sampling the tomato crop. A promising method is that of recording certain data on only a proportion of the total number of replicates at each harvest.

Experimental techniques with mushrooms

Work on this subject is continuing with Mr. Flegg of the Horticulture Department. A pot experiment was carried out to test if the variability of yields within each block of an experiment was reduced by mixing the compost very well before filling the pots in the block. The normal method is to fill the pots successively with compost taken directly from the heap. The mixing did not reduce the variability.

Variability may result from the mushrooms on a given plot being picked, on the average, at a different stage of maturity from those on another plot. An experiment was carried out in which mushrooms were picked at four stages: as buttons, cups, flats and late flats. The stage of picking had a marked effect on yield. This appears therefore to be a real source of variability and a method of adjusting for it is being sought. Other results from this work are reported by Mr. Flegg (page 87).

Work for outside bodies

The Statistician continued to serve on the Bulbs, Flowers and Glasshouse Working Parties of the Agricultural Improvement Council's Experimental Horticulture Committee. The work involves advice on the planning of experiments at Experimental Horticulture Stations and analysis of the results. A total of 44 experiments has been analysed, involving 1,395 plots and an average of 4.1 variates per plot. A substantial proportion of the computation was done on the electronic computer at Rothamsted Experimental Station.

5. ENTOMOLOGY

by

N. W. HUSSEY

Mushroom Phorids (N. W. Hussey)

Advantage was taken of an exceptionally heavy outbreak of *Megaselia halterata* at a local farm to study the population trends from spawning to the end of cropping. Whereas the highest populations reported in the famous "Phorid" year 1953 were about 50 larvae per 30 grammes of compost, the current observations were made on a population as high as 400 larvae/30 g. The most heavily infested trays lost all mycelium immediately below the casing layer. Experiments in jars of spawned compost showed that extensive damage to the mycelium occurred at population densities above 200/30 g., and on the basis of present experience it appears that serious damage is likely to occur if populations exceed 100/30 g. The study of population trends suggested two conclusions especially significant in view of the vast numbers of flies present throughout the cropping period: (a) that the larval population declined steadily from three weeks after spawning and (b) that few eggs were laid in the first week after casing when the trays were in the cropping house. A trial on the effect of Phorid oviposition on mycelial development was made by exchanging trays, at different stages of spawn growth, between the Institute and a heavily infested commercial farm. Although the larvae had no effect on yield, it was concluded that the mould growing on the dead adults may have been competitive with the mushroom mycelium and responsible for the yield reduction of about $\frac{1}{2}$ lb./sq.ft.

Insecticidal tests on the larvae *in vitro* were unsuccessful owing to high mortality in the control treatments apparently caused by the flotation techniques used to extract them from compost. Later studies were made by exposing jars of newly spawned compost in cropping houses with a high fly population. These showed that synergised pyrethrin dusts significantly reduced oviposition, whereas BHC and malathion neither prevented oviposition nor killed larvae even at concentrations of 50 p.p.m. Comparative laboratory trials showed that malathion killed more adults than BHC or aldrin.

The promise shown by pyrethrins was followed up by applying heavy doses to newly spawned beds in the absence of flies (14 lb. of 0.25% pyrethrin synergised with 2.5% piperonyl butoxide per 1,000 sq. ft.). There was a reduction in yield of about $\frac{1}{4}$ lb. per sq. ft., but as control methods would utilise much lighter doses there seem to be no cultural objections to the use of this material.

Mushroom Cecids (I. J. Wyatt)

In the laboratory, studies on the comparative morphology of Cecid larvae continued and, to facilitate determinations of Cecidomyiidae now being undertaken on behalf of the Commonwealth Institute of Entomology, an extensive card-index system was organised.

A series of experiments was completed in the cropping house which confirmed earlier work on the economic effects of Cecid larvae. Observations on population growth of *Mycophila speyeri* were made by introducing different numbers of larvae into trays (6 sq. ft.) at several intervals after spawning. Population growth was approximately exponential until a total of about 50,000 larvae was reached, when the *rate* of population growth declined, but populations continued to rise to a maximum of 190,000 larvae per tray. Contamination of sporophores began when larvae exceeded 1,000 per bed, and reached 90% when populations were about 63,000 per bed.

For comparison with a similar study on *Heteropeza* made last year observations were made on the spread of *M. speyeri* from a central inoculation on large beds (13 ft. x 4 ft.). On these larger growing areas the degree of contamination of the sporophore was very low compared with trays. The detectable "front" of the populations moved out at a rate of $1\frac{1}{2}$ in. per day. The population distribution was not "normal" as it always remained inordinately high about the centre of inoculation. Thus movement was presumably not random. The data from these experiments are being examined by Dr. J. G. Skellam of the Nature Conservancy to ascertain whether the behaviour of the two species can be explained by mathematical models.

The most satisfactory control for Cecids has been attained by incorporating aldrin in the casing, before application to the beds, at a concentration of 10 p.p.m. Many growers have questioned the desirability of such an "insurance" method, and a trial was made of surface application of aldrin emulsions when sporophore contamination first became apparent. The material was applied at $5\frac{1}{2}$ fl. oz. of 15% aldrin per 1,000 sq. ft. The use of aldrin in this way could result in undesirable residues on the mushrooms but, with the co-operation of the Shell Chemical Company, it was demonstrated that, if application were made to beds which had been "picked hard", the residues did not exceed 0.3 p.p.m. dieldrin. In view of the low consumption of mushrooms *per capita* this could probably be regarded as safe. However, as the damage caused by *M. speyeri* larvae is greatest on the first flush and decreases subsequently, the method only reduced the total loss by 50%. While some amelioration of damage is therefore possible by watering beds with aldrin it is safer to use the treated casing technique.

Although it has not proved possible previously to demonstrate significant losses of crop in the presence of large Cecid populations on normal composts, several attempts have been made to determine whether a greater effect could be demonstrated if the mycelium were growing under subnormal conditions. However, each experiment failed to produce a sufficient difference in crop weight between the "inferior" and normal crop even in the absence of Cecids. On two occasions the inferior crop was grown on compost removed from the stack prematurely, and in the other the beds were inoculated with (what was believed to have been) a weak strain of spawn. The combined results of the three experiments demonstrated a 14% reduction of yield by *Heteropeza*. It is unlikely, however, that comparable infestations and losses would ever be achieved in commercial practice.

Agromyzid Leaf-miners (Barbara Gurney)

Adult *Phytomyza atricornis* were induced to oviposit on lettuce plants which had been grown outside for four weeks over the winter solstice. Subsequent development of the progeny was not affected by this host treatment and it must be concluded, following the experiments reported last year, that this Agromyzid has no true diapause.

Observations of natural infestations by leaf-miners showed that oviposition tends to be localized on foliage in the lower shaded portion of the plant or on completely shaded plants. This suggests that the adults may have some ecological preference, such as shelter from wind or light, or that leaves grown in these conditions are preferred. Adults were confined on young and old leaves of lettuce plants by several techniques. None of the methods was completely satisfactory as the flies did not oviposit readily in confined spaces, but apparently fecundity was not affected by leaf age.

In the 1959 Report reference was made to the parasite complex associated with *P. atricornis* differing between host plants. To facilitate future studies on this interesting observation the life history and larval morphology of the following four parasites has been worked out: *Rhizarcha areolaris* (Ness), *Diglyphus chabrias* (Walker), *Cirrospilus vittatus* Walker and *Chrysocharis melaenis* Walker.

During these studies it was noticed that *atricornis* larvae produced several different frass patterns in the mines. Adults bred from larvae making two of these patterns were segregated and inbred. The progeny bred true for frass pattern, and yet the two strains were interfertile. A careful study of the muscle scar patterns and posterior spiracles on the puparia revealed differences between the strains. Thus the polyphagous species *P. atricornis* may, in fact, consist of several strains with different, but overlapping, host ranges.

The survey of Agromyzids on ornamental plants was continued, and twenty host plants were recorded during the year.

Glasshouse Red Spider Mite (*Tetranychus urticae* Koch) (N. W. Hussey, W. J. Parr and Valerie A. Cooke)

Early in the year our attention was drawn to the difficulties being experienced by Lea Valley cucumber growers in controlling red spider mite. The evidence on most nurseries strongly suggested that resistance to acaricides was increasing. The research work subsequently started at the Institute was undertaken jointly by the Crop Protection and Entomology Departments. The following report presents a complete summary of the results obtained.

Samples of mites from affected nurseries were received at intervals during the summer, and test populations were built up on potted cucumbers. These were dipped in a range of concentrations of Kelthane, schradan and parathion, and high levels of resistance to the organophosphorous compounds were demonstrated in some of the strains. There was no detectable resistance to Kelthane, however, on these dipped plants.

The technique of dipping large populations on potted plants was demanding in time, space and labour and was not suitable for more refined studies demanding the demonstration of small changes in resistance levels. With parathion an improved technique was found in which mites were placed for one hour on discs of treated filter paper and then removed to leaf discs for a further 24 hours before mortality assessment. If these filter paper discs were supported on a pin loss of test animals, due to random wandering by the mites, was negligible. The data on resistance of field strains obtained by this method suggested that the populations were very heterogeneous and that future work would necessitate using inbred pure lines of mites.

Tests for Kelthane resistance proved more difficult as no mortality, even at the highest concentrations, occurred on treated filter papers. Use of leaf discs dipped in Kelthane and then dried before testing gave better, but by no means satisfactory, results. Where the Kelthane was applied to the upper surface of the leaves of growing plants, while the mites were contained on the lower surface, striking differences in resistance could be demonstrated. The apparent conflict between the growers' experience of field resistance and our failure to demonstrate this by dipping techniques may be explained by the poor distribution of spray known to be achieved on the lower surface of cucumber leaves. While 100% mortality occurs at normal doses if the chemical is deposited on the mites, field strains have different degrees of resistance to Kelthane translocated between the upper leaf surface and the feeding zone of the mites.

A series of large-scale control experiments in five cucumber houses was attempted in July but had to be abandoned as the mites failed to colonize the plants even though these were infested on three occasions. Analysis of the cause of this failure continued for six months, and ten experiments were made to eliminate possible contributing factors. None of these tests produced results comparable with the complete lack of population increase in the cucumber houses, but there is definite evidence that the sulphur generators, used to control cucumber mildew, depressed population markedly. In one experiment nightly fumigation of young

cucumber plants resulted, after five weeks, in populations only a quarter those on untreated control plants. It is possible that the degree of control achieved is affected by the humidity at the time of vaporisation, and experiments are in progress to test this.

To confirm American experience, crosses were made between susceptible and parathion-resistant strains and it was shown that the hybrids were completely resistant, confirming the belief that the character is controlled by a single dominant gene.

The diapause behaviour of *T. urticae* was also investigated because, although earlier workers had claimed that if the daylight length were less than twelve hours during the deutonymphal stadium the resultant females would enter diapause, the pest was troublesome even in January and February in the Lea Valley. The experiments made were difficult to interpret as it eventually transpired that the strain of mite used had lost the ability to enter diapause, although it had only been cultured continuously for 2—3 years under artificial conditions. More limited work on other strains of mites suggests that there may be strain differences in the relative balance between daylight duration, temperature and nutrition needed to initiate diapause. Short daylight and low temperatures are sufficient to cause some mites to diapause, but large scale hibernation is often only initiated when starvation affects mites at the same time as the other factors.

Experiments on the optimum environmental conditions for diapausing mites showed that the mites succumbed more quickly to high temperatures than low humidities and that the optimum survival was probably at about 40°F. with high humidity.

Diapause was terminated by exposure to a temperature of 75°F. after 36 days at 43°F., which confirms evidence from other workers that it is possible for mites to terminate diapause, under suitable conditions, in January and February.

6. MYCOLOGY

by

P. H. WILLIAMS

Didymella Stem Rot of the tomato (P. H. Williams)

Transmission by handling

Tomato plants, variety 'Potentate', were grown in the border of house X. When large enough, the end plant of each row was inoculated in two places with *Didymella lycopersici*. When these plants died they were replaced with inoculated plants in pots. Four treatments were applied :—

- (i) Lesions cut and the knife used immediately to remove leaves and shoots from the other plants in the row.
- (ii) Leaves and shoots removed with a sterilised knife.
- (iii) Lesions handled before handling leaves and shoots.
- (iv) Leaves and shoots removed by hand without previously touching infected material.

In each treatment one leaf was removed from each of the six uninoculated plants in a row each week from 31st May until 30th August. No lesions developed until the end of September, and then only six developed on the 72 wounded plants. Three lesions developed on unwounded stems, and as some of the six lesions appeared on wounds made in June and July it is probable that most resulted from airborne infection and not from handling. It does not appear, therefore, that handling the plants during cultivation is an important way of spreading the disease.

Effect of metham-sodium and chloropicrin

Steaming makes soil very susceptible to infection and growth of *D. lycopersici* with resulting high incidence of disease in the tomato crop (2), but it is not known how metham-sodium or chloropicrin affects infestation of soil with *D. lycopersici* or elimination of that fungus from the soil.

As no glasshouse was available, unsterilised soil was treated in flasks with rubber bungs fitted with glass tubing for subsequent aeration. After treatment the flasks were kept sealed for six days, then aerated by passing filtered air through them for five hours, and finally inoculated with a spore suspension of *D. lycopersici*. After incubation for 18, 37 and 52 days the soils were plated but no *D. lycopersici* was found. Tests by the Crop Protection Department showed that the metham-sodium was not eliminated by the method of aeration used and this no doubt prevented growth of the *D. lycopersici*, as few colonies developed in plates poured from soil treated with metham-sodium. Chloropicrin caused only about 12% reduction in the numbers of organisms in the soil, so *D. lycopersici* was unable to develop in it.

When autoclaved soil in flasks was inoculated with *D. lycopersici* and, after incubation, treated with metham-sodium or chloropicrin, no fungus developed as it did in the control flasks. It seems likely, therefore, that these compounds will eliminate *D. lycopersici* from infected glasshouse soil.

Verticillium Wilt (P. H. Williams)

Two isolates of *V. albo-atrum* and three of *V. dahliae* from wilted tomatoes, and a culture of *V. dahliae* isolated from wilted chrysanthemums, were tested to select strains for future work.

Tomato plants inoculated with *V. albo-atrum* were stunted and wilted severely, most of the leaves being involved. They did not recover, contrary to previous experience. *V. dahliae* from tomato caused only mild wilt, with the lower leaves flagging, and that from chrysanthemum caused no obvious symptoms, although it was re-isolated from one plant.

The failure of the plants inoculated with *V. albo-atrum* to recover might have been due to restriction of growth in the 6 in. pots, so later plants in 6 in. and 9 in. pots were inoculated at the same time, using one culture each of *V. albo-atrum* and *V. dahliae*. With *V. albo-atrum* wilting was severe in both series, and in both two plants out of six recovered, possibly because of the higher humidity in the autumn. Plants inoculated with *V. dahliae* reacted as before, only the lower leaves wilting.

Cucumber Black Rot (P. H. Williams)

This disease appears late in the season and causes rotting of stems and fruit, often leading to a premature end of the crop.

Plants growing in large pots were inoculated on four occasions during the summer and autumn with *Mycosphaerella melonis* and although fruits were readily infected, no stem was. Possibly the rather thin, hard stems of plants growing in pots are not readily infected by this fungus.

Cucumber Mildew (Olwen M. Stone)

During the year tests continued on the susceptibility of species of *Plantago* to cucumber mildew and vice versa, but no cross infectivity was found. *Sonchus asper*, however, was still highly susceptible to cucumber mildew. In laboratory experiments, spores from cucumber were still capable of causing infection after seven days storage on a dry microscope slide, and after eight days on either moist or dried leaf discs. Work on the problem of alternate weed hosts of the cucumber mildew has now been discontinued.

Carnation Wilt Diseases (Marion H. Ebben)

In the experiment in house E1, designed to test the longevity of the wilt fungi *Verticillium cinerescens* and *Fusarium oxysporum* f. *dianthi* in soil, several methods were used, unsuccessfully, to isolate them from soil in which tomatoes or chrysanthemums had been grown. When carnation cuttings were potted in soil from plots inoculated with *V. cinerescens* in 1959, some of the plants in soil in which tomatoes had been grown for two seasons wilted, but those in soil from other plots did not.

Unsuccessful attempts were also made to isolate the pathogens from the roots of chrysanthemums growing in infested soil.

Carnations planted in plots which had borne diseased carnations the previous year wilted more rapidly than in the previous crop, indicating a build-up of infection.

Thielavia reticulata sp. nov. (Marion H. Ebben)

A *Thielavia* isolated from healthy carnation roots was found by Dr. C. Booth of the Commonwealth Mycological Institute to be a new species. It will be described soon in a joint paper with Dr. Booth.

A chrysanthemum root rot (Marion H. Ebben)

During the past fifteen months chrysanthemums from three sources showed poor growth, wilting and necrosis of the lower leaves. In some plants the roots were rotting and the cortex at soil level was slightly decayed.

The causal fungus was isolated from the roots and stem bases of these plants; in culture it has a branched septate mycelium, pale grey at first, later becoming dark grey. Abundant dark grey to black pseudo-sclerotial masses irregular in shape and size are formed in the mycelium. It resembles the *Phoma* sp. described by Kemp (1) as the cause of a root rot of chrysanthemums in Canada.

Petal Blight (*Itersonilia perplexans*) (Doreen G. Gandy)

Itersonilia perplexans was isolated in late autumn from many blossoms of outdoor chrysanthemums, dahlia and sunflower. The conditions necessary for its development are now being studied.

"Watery Stipe" disease of mushrooms (Doreen G. Gandy)

Cropping experiments

(a) *Effect of time of infection on the crop.* Beds 12 ft. × 4 ft. were inoculated in the centre with compost containing affected mycelium at spawning, at casing, at the appearance of the first pinheads and after the first flush. In the beds inoculated at spawning there was virtually no crop within about three feet from the site of inoculation. The size of the bare area increased slightly during subsequent flushes, and cropping ceased early. Similar results were obtained from beds inoculated at casing, but the affected area was smaller. The effect of the later inoculations was imperceptible. Cropping was reduced by about half on beds inoculated at spawning, and by about one third on those inoculated at casing.

Abnormal sporophores, usually with greatly swollen stipes and vestigial gills, were common on the beds receiving the first two treatments and occurred mainly at the edge of the bare areas. However, similar abnormalities appeared later on control plots, and as they had been observed in other non-pathological experiments, where the same strain of spawn had been used, their cause might have been genetical. This was investigated in a later experiment.

As in the past, the mycelium had largely disappeared from the bare areas, and mycelium isolated from the periphery of such areas produced slow-growing cultures on agar media.

(b) *Disinfection of infected houses.* An experiment was done to ascertain whether the normal "cooking out" of a mushroom house at the end of cropping would effectively disinfect it after an outbreak of "Watery Stipe". Infected compost was heated at 42°C. for twelve hours before being inoculated into beds at spawning time. They produced healthy crops.

(c) *Spawn trial.* Arising from the difficulty in determining whether the sporophore abnormalities observed in (a) were due to "Watery Stipe" or some factor inherent in the strain of mushroom used, a spawn trial was done, testing eight commercial spawns at two spawning rates.

One sporophore abnormality was common: in its mildest form the gill lamellae were wavy instead of straight. There was a gradation from this to the next stage, anastomosis of the lamellae. There was also progressive under-development of the lamellae, so that in the worst cases the sporophores were sterile. The frequency of these abnormalities varied slightly with the different white strains. They were almost absent from the one cream variety grown.

Other abnormalities which have been associated with "Watery Stipe", e.g., waterlogging of tissues, curvature of stipes and death of immature sporophores, were absent.

Because of these results the strain used in future "Watery Stipe" experiments will be the white one which produced the fewest abnormalities.

Laboratory experiments

The investigation into the behaviour and cause of abnormal mycelial growth associated with "Watery Stipe" continued.

Numerous unsuccessful attempts were made to obtain suspensions in which all cells were ruptured, to see if such suspensions could still transmit the abnormality, but some cells always survived. Abnormal mycelium was also treated with KCN, as in the isolation of some plant viruses. Abnormal mycelium was macerated in sterile ascorbic acid—phosphate buffer (pH 7.0). Excess 0.3% KCN was added to the suspension which was then centrifuged to precipitate the mycelium. The KCN was drained off and the pellet resuspended in buffer. Discs of normal mycelium were dipped in this suspension and put on plates of agar. The suspension was also plated out and again produced colonies. Accordingly, stronger solutions of KCN were used, but these experiments are not yet complete.

Other methods used to extract a possible virus included ultra-centrifuging mycelium, followed by further centrifuging of the pellet in a sucrose density gradient. Two zones were extracted from this but neither transmitted the abnormality. Chloroform-butanol extracts of mycelium also gave negative results.

A range of test plants such as are used in virus investigations was also employed. They were kept in complete darkness for 24 hours before inoculation, which was done by rubbing the leaves with a suspension of mycelium in ascorbic acid buffer solution. The results were negative.

One experiment examined the possibility that Cecid larvae might transmit the disorder. Larvae were allowed to feed on abnormal cultures for several days before being transferred to normal ones. Mycelium from the latter was then isolated and grown in the absence of larvae. No transmission was apparent.

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7. VIROLOGY

by

M. HOLLINGS

Studies continued on the epidemiology of tomato mosaic, the analysis of the virus complex in carnations and chrysanthemums, and the development of techniques for producing virus-free clones of carnation and chrysanthemum. The lack of suitable glasshouse facilities limited the scope of work, but the acquisition of a Spinco Model L preparative ultracentrifuge was of the greatest value to the department, enabling virus purification and preparation of antisera to be resumed. In particular, the technique of density gradient centrifugation formed a major item of investigation.

Visit to the United States

M. Hollings spent three and a half months in the U.S.A. on an A.R.C. Travelling Fellowship, visiting universities, research stations and growers of ornamental and glasshouse crops. Two months were spent in the Plant Pathology Department, University of California, Berkeley, studying recently developed techniques in virus purification, immuno-electrophoresis, serology and tissue culture. Antisera to some viruses of ornamental plants were taken to the U.S.A., enabling American and British isolates of these viruses to be compared. In this way the serological identity of American and English isolates of carnation mottle, carnation ringspot, hydrangea ringspot, chrysanthemum aspermy and lucerne mosaic viruses, among others, was confirmed by precipitin and gel-diffusion tests. As in our tests in Britain, every carnation plant of 230 tested in the U.S.A. was infected with mottle virus.

Density gradient centrifugation (M. Hollings and Olwen M. Stone)

One of our principal uses of the Spinco ultracentrifuge was density gradient centrifugation; layers of sucrose solutions of increasing density were prepared in special tubes with the dilute solution at the top. Preparations from plant material were carefully placed on the top of such gradient columns, and the tubes centrifuged. Different components in the preparations sedimented at different rates and to different levels in the sucrose columns, depending upon their particle size and density. The components were often seen as sharply-defined bands in the tubes (Plate 2), and these could be extracted by hypodermic needle through the wall of the tube, and tested for infectivity, serological activity and the presence of particles. In this way certain plant viruses were separated from one another, and from the constituents of normal plants. Experiments have been concerned with improving the conditions and scope of the technique for work with viruses of carnation, chrysanthemum and some other plants. Chrysanthemum sap contains tannins and oxidising systems that render the method unsatisfactory without prior partial purification but, contrary to many reports, relatively crude sap preparations from carnation and *Nicotiana clevelandii* gave satisfactory results with some viruses.

The results are recorded under the crop plant concerned.

Intracellular inclusions (Margaret E. Norrish)

The study of intracellular inclusions in carnations and some other plants has begun in an effort to establish a further technique for virus identification and diagnosis.

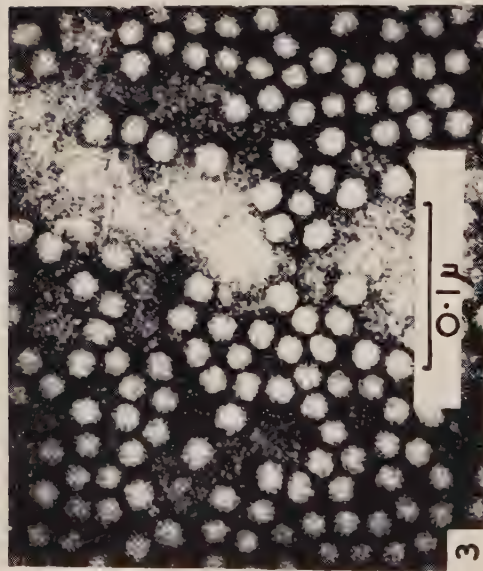
CARNATION VIRUSES



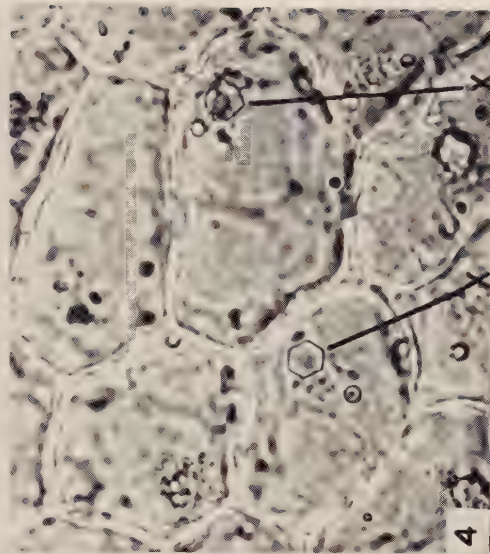
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1. Mottling of calyx in carnation, caused by carnation vein mottle virus. 2. Density gradient centrifugation of carnation mottle virus; narrow light-scattering zone at the 24% sucrose level in gradient column. 3. Electron microgram of particles of carnation mottle virus. 4. Crystalline intracellular inclusions of hexagonal pyramid shape ($\times$).

Epidermal strips from the petals and leaves of carnations provide convenient preparations for studying the cells *in vivo*. As virus-free material of commercial carnation varieties was not available, healthy clonal Chabaud and seedling carnation plants served as control tissue for the work. No inclusions were found in the epidermal cells of either of these control groups, and it is tentatively assumed that virus-free carnations would not have intracellular inclusions.

The inclusions found so far in infected carnations may be broadly divided into two types: granular bodies which stained densely with 0.5% phloxine solution, and crystalline inclusions which did not take up this stain. The granular inclusions found so far were oval to spherical bodies, usually one to a cell. The crystalline inclusions were of hexagonal, triangular and pyramidal form (Plate 4). The pyramidal inclusions had either triangular or rectangular bases.

Carnation (M. Hollings, Olwen M. Stone and Margaret E. Norrish)

1. Indexing carnations

Tests on commercial varieties of carnation have continued, and every plant tested has been infected with at least mottle virus, including some first- and second-year seedlings. We need virus-free carnations to assess the damage caused by individual viruses, and although seedling Chabaud plants have been apparently virus-free, those inoculated have not given the characteristic symptoms of certain carnation viruses and are therefore unreliable either for diagnostic and experimental work, or for assessing the relative economic importance of the viruses. Seedlings of 'Joker' and several 'Sim' varieties have therefore been raised to provide virus-free clones for this purpose.

Seedling Chabaud clones did, however, react to vein mottle virus with leaf mottling and spotting of a darker green, and a prominent light and dark green mottling on the calyx (Plate 1); this latter symptom has not been observed with any other carnation virus.

2. Selection of clones of *Dianthus barbatus* L. (Sweet-william) as indicator plants

Further tests on batches of seedling clones of *D. barbatus* have emphasised the diversity of their reaction to carnation viruses—especially to mottle virus, to which many clones proved either resistant, or tolerant, carrying mottle without symptoms and in very low concentration. Some resistant clones have been used in attempts to filter out mottle virus from virus mixtures.

3. Seed transmission tests

Further tests have given no indication that any of the carnation viruses is seed-borne.

4. Carnation mottle and ringspot viruses

Studies on the infectivity and antigenicity of different fractions obtained during purification procedures continued; preparations of ringspot formed a narrow, clearly-defined zone at 24% sucrose level when centrifuged for 120 minutes in the Spinco R.25 rotor at 25,000 r.p.m., in a density gradient column of 10–60% sucrose in M/30 phosphate buffer pH 7.6 (Plate 2). Maximum infectivity, antigenicity and particle concentration occurred in the zone. This method (equilibrium zone centrifugation) sediments particles according to their density, and mottle virus sedimented to the same level as ringspot, although infectivity and serological activity of mottle virus were not confined to the immediate region of the visible zone.

Rate-zone centrifugation, in a more shallow gradient of sucrose concentrations for a shorter time (10–35% sucrose, 30–45 min.) also resulted in mottle and ringspot viruses sedimenting

to the same level, indicating that the particles of the two viruses are of very similar size, and it is not possible to separate or distinguish between them by this method. Electron micrograms, kindly made by Mr. H. L. Nixon at Rothamsted, confirmed that the particles of the two viruses were indistinguishable (Plate 3). Nevertheless, mottle and ringspot viruses differ greatly in many properties and in the range of plants they infect; also ringspot can be eliminated by heat-treatment or by tip culture, whereas mottle can not. The two viruses are serologically unrelated, and in carnation plants ringspot causes symptoms different from, and much more severe than, mottle.

Previously, mottle virus multiplied without symptoms in the inoculated leaves of *Tetragonia expansa* Murr. without invading the plant systemically. Recently, however, from autumn to spring, diffuse local chlorotic spots developed in the inoculated leaves of *Tetragonia* a few days after inoculation with mottle virus, and sometimes the plant was systemically invaded. However, the concentration of mottle virus in *Tetragonia* leaves, as measured by comparative serological titre and assay of leaf discs inoculated to *Chenopodium*, was as high in areas of inoculated leaves without any lesions as in the lesions themselves. It may be that the lesions in *Tetragonia* were caused, not by mottle, but by a hitherto unrecognised carnation virus. All tests so far detected only mottle.

When *Tetragonia* leaves were inoculated with mottle virus from different sources, local and systemic infection usually occurred. Challenge inoculations to systemic leaves with mottle virus of the type strain resulted in as many or more lesions per leaf as did the original inoculation. Comparative inoculations to *Chenopodium* from sample discs cut from the *Tetragonia* leaves after the first and the later inoculations indicated that not only was there no protection, but mottle virus reached a far greater concentration following the second inoculation.

5. Concentration of mottle virus in carnation shoot-tips

In connection with tip-culture work, the concentration of mottle virus in different parts of the shoot apex was assayed. Leaf primordia and meristem domes were excised, macerated under a dissecting microscope in a measured drop of phosphate buffer to give 1 : 500 vol./vol. dilution, and inoculated to *Chenopodium*. Mottle virus was detected not only in the first pair of leaf primordia (usually included in explants cultured to obtain "virus-free" clones), but also in many of the meristems themselves. Comparative half-leaf inoculations to *Chenopodium* indicated that the concentration of mottle virus was lower in meristematic tissue than in young, fully developed carnation leaves.

6. Tip culture of carnations (Olwen M. Stone)

The experiment begun last year was completed. Three hundred plants of the varieties 'White Sim' and 'William Sim' were grown in randomised blocks, from cuttings to flowering. Tips were taken from them every three weeks from July to February and placed on sterile agar nutrient medium in tubes. There was up to 30% bacterial contamination in tips taken from freshly rooted cuttings, suggesting that bacteria had been washed down to the leaf axils by mist and overhead watering in the rooting bench; later batches had less than 5% contamination. Rooted cuttings produced four to eight tips per plant and, in the early stages, one plant from each block was used at each sampling. Flowering plants produced up to 100 tips each and one plant was then taken at random for each sample.

The proportion of tips that rooted (30 to 40%) was uniform throughout the period of the experiment except for two samples in December when only 8% and 2% of the tips rooted. The tips from 'William Sim' consistently rooted better than those from 'White Sim', but the

reason for this is not known. When tips $\frac{1}{2}$ to 1 mm. in length were taken, 30 to 80% rooted, but only 5% of tips smaller than $\frac{1}{4}$ mm. rooted. The complementary experiments on the virus content of meristems suggest that, although the smallest tips might be free from virus, any that included leaf primordia would not be. Different culture media are now being tested to obtain maximal rooting of the smallest tips. Contrary to previous opinion, the terminal tips rooted less well than the axillary ones (10% against 40% for 'William Sim'), but some flower initials rooted.

Chrysanthemum (M. Hollings)

1. Stunt

American isolates of this virus, and some English ones, were not eliminated when plants were grown at 33°C. or 38°C. for 4—6 weeks. Attempts to use higher temperatures to reduce the long "incubation period" of stunt virus in the indicator variety 'Mistletoe' were unsatisfactory, for when grown at 33 or 38°C. after graft-inoculation, the diagnostic symptoms of stunt did not develop. Control grafts, maintained at 18—22°C., developed typical stunt symptoms in 9—17 weeks. Nevertheless, stunt virus multiplied and invaded the shoot tips of the plants grown at the higher temperatures.

Further evidence was obtained that stunt virus was not eliminated by growing shoot tips (comprising the meristem and first pair of leaf primordia) in sterile culture tubes after the plants had been grown at 38°C. for six weeks.

Work continued on the purification of stunt virus in the hope of developing rapid diagnostic tests for indexing chrysanthemums. The lack of a host plant on which the virus concentration could be assayed quantitatively, and the long "incubation period" in chrysanthemum (2—8 months) impeded progress. It was not possible to obtain consistent results with density gradient centrifugation methods, and although partial purification by precipitation of the virus with ammonium sulphate, by differential centrifugation, or by butanol-chloroform extraction, all yielded infective preparations, it was not possible to measure how much of the original infectivity was lost in the different processes.

No insect vector of stunt virus is known at present, and attempts to transmit the virus from chrysanthemum to chrysanthemum by the Glasshouse Red Spider Mite (*Tetranychus urticae* Koch) were unsuccessful. Further tests indicated that dipping the cutting knife in a 5% solution of tri-sodium phosphate did not prevent some spread of stunt when cuttings were taken alternately from healthy and infected plants.

2. Vein mottle and other mosaic viruses

Experiments continued on the relationship between the different leaf-mottling viruses isolated from chrysanthemums, and their occurrence in different chrysanthemum varieties. There are many varieties in which all plants tested contained the same or closely similar viruses, suggesting that the entire variety was infected. Several of the virus isolates induced brown streaks on the florets of 'Yellow Fred Shoesmith' and some other varieties. *Nicotiana clevelandii* reacted with systemic vein clearing, leaf mottle, distortion and crinkling to many of the isolates, though these symptoms differed greatly in virulence.

Tomato mosaic (L. Broadbent)

Work has continued on the epidemiology of this disease, especially on the following sources of virus and on the losses caused by tobacco mosaic virus (TMV).

(a) *Seeds*

2,090 seeds from infected fruits, cleaned by fermentation, washed in water and dried, have been sown individually to obviate pricking out. None has produced an infected seedling. TMV was demonstrated on or in the testas by grinding a sample of each batch in water and inoculating *Nicotiana glutinosa*, but none could be demonstrated in shoots or roots. On the other hand, 18 out of 1,170 seedlings that were pricked out showed mosaic soon afterwards. Experiments are continuing to find how the seedlings become contaminated from the testas during this operation, and how soon the virus in the testas is inactivated after planting in soil.

All the treatments for freeing tomato seeds from TMV that are recommended in the literature have been compared with each other. Many apparently lower the concentration of virus in or on the testas, without affecting germination, but none eliminates it. More work is needed to find if the lower concentration is caused by inactivation or inhibition, and if such treatments prevent infection during pricking-out.

(b) *Smoking tobacco*

60 out of 62 samples of foliage from commercial tomato crops were infected with TMV that caused necrotic local lesions on, but did not invade systemically, a special type of 'White Burley' tobacco. In contrast, 32 out of 33 samples of smoking tobacco were infected with TMV that did not cause necrotic local lesions but invaded the 'White Burley' tobacco systemically; these viruses reacted similarly after passage through tomato. Four other brands of cigarettes containing Turkish tobacco caused local lesions on 'White Burley' as well as invading systemically, but after passage through tomato these viruses caused symptoms of a type different from those caused by tomato mosaic. The evidence from these few tests suggests that smoking tobacco is not a common source of virus in British tomato crops.

(c) *Soil*

Experiments on transmission of TMV through the roots or lower stems of tomatoes were done in concrete carnation beds, the foliage of each plant being surrounded with a polythene cylinder to prevent infection through the leaves. During ten weeks after planting out, three out of 72 plants were infected when grown in soil that had carried a diseased crop the previous year, and the same number when the plants were transplanted into clean soil overlying old contaminated soil. None was infected in old soil that had been steam sterilized or in the control plots filled with John Innes compost.

To find the effect of metham-sodium as a sterilizer, a small quantity of infected tomato debris was mixed with sand, and half the mixture treated with metham-sodium eight weeks before planting. 36 out of 72 plants were infected in the untreated plots, but 66 out of 72 in the treated. More work needs to be done to find if the effect is similar in soil, and the cause of this great increase in infection.

Samples of the leaves and roots of all plants were tested for TMV. 16 out of 108 were infected in the roots only; apparently virus had not become systemically distributed when the experiment was terminated.

In a second experiment no infection occurred in the sand plots after they had been steam sterilized. In this experiment also, the four corner plants of each plot (3 rows of 3 plants, 14 in. apart) were inoculated with TMV after planting into clean compost. After two months shoots and roots of the 120 plants whose roots were thus in contact with those of infected plants, were tested but none was infected. Further evidence that infection through root-contact is not common was obtained in the experiment on yield reported below.

Effects of TMV on yield

An experiment in house D2 tested the effects of a moderately severe isolate of tomato mosaic virus on leaf symptoms, fruit yield and quality in two tomato varieties, 'Moneymaker' and 'Potentate'. The plants, sown 10th December, 1959, were divided into six replicates of four treatments, plots of 20 plants of each variety being separated by polythene sheeting 4 ft. wide. The treatments were:—

- (1) infected 3rd March when the petals of the first flower of the first truss were reflexed
- (2) infected 14th April when the first flowers of the fifth truss reflexed
- (3) infected 31st May when 10—12 trusses had set
- (4) uninfected. Strict precautions to prevent spread of virus were successful, only one of the six uninfected plots becoming infected, during late June.

Leaf symptoms, manifest as yellow-green mottle, smaller size and puckering, developed about two weeks after inoculation, and early infection caused plants to grow much more slowly than those infected later. Late infection caused mottle only in young shoots. Lower leaves died earlier on infected plants, which were "harder" and more brittle than uninfected ones.

About 12 lb. of fruit per healthy plant was picked between 2nd May and 7th September. 'Moneymaker' produced a slightly larger crop of smaller fruits than 'Potentate' but the effects of virus were similar in every respect in the two varieties.

Soon after the plants became infected the larger fruits ripened prematurely and tended to fall off. Fruit set was adversely affected by the first two infections, and weight yields were 20—35% lower than the controls during May and June following infection on 3rd March, and during June and July after infection on 14th April. Smaller fruits were the main cause of loss in the late-infected plots. The losses over the whole season were similar despite the big differences in infection date, averaging about 15%.

Necrotic pitting, bronzing and severe mottle of the fruits, mainly caused by TMV, were not significantly different in the plots infected before fruit set and in the control plots (about 2%), but affected fruits were numerous in plots infected on 14th April (about 10%) and on 31st May (about 31%). Two weeks after infection these symptoms affected most ripening fruits, but after another three weeks the number affected gradually decreased.

Because of the effect on fruit quality as well as yield, later infection caused greater financial loss.

Review of literature

A thorough review of the literature of the epidemiology of tomato mosaic has been undertaken and is published as a separate article on page 96.

Miscellaneous (M. Hollings, Olwen M. Stone and Margaret E. Norrish)

(1) *Dahlia*

Experiments done in 1959 were repeated in 1960, when dahlia plants showing different symptoms within the range of dahlia mosaic were compared for their reaction on standard indicator clones of dahlia, on *Verbesina encelioides*, and on a range of test plants. Although all isolates were readily transmitted by *Myzus persicae* and most of them induced similar symptoms in our standard dahlia indicator clone, none caused symptoms in *Verbesina*, which is reported to be a diagnostic indicator plant for dahlia mosaic virus. Investigations continue on the identity of the virus or viruses present, including cytological studies on the intracellular inclusion bodies present in cells of some infected plants.

(2) *Hydrangea*

Hydrangea plants infected with hydrangea ringspot virus were grown at 38°C. for four weeks, then tip cuttings were struck. The few surviving cuttings still contained ringspot virus when tested some months later.

(3) *Oleander*

A plant of *Nerium oleander*, with black spots on some older leaves, was markedly less vigorous than some other clones of the same species. When shoots from the affected clone were grafted to the more vigorous clone, a few black leaf spots developed five weeks later, but there was no subsequent loss of vigour. No spots appeared on the ungrafted control plants.

(4) *Pelargonium*

Partially-purified preparations of pelargonium leaf curl virus from *Nicotiana clevelandii* and *Gomphrena globosa* gave a clearly-defined zone, associated with maximum infectivity, in density gradient centrifugation tests, but crude sap from infected pelargoniums did not.

A pelargonium plant that showed typical symptoms of leaf curl in 1958 was propagated each year by cuttings. No symptoms appeared in any of these cuttings, nor could leaf curl virus be isolated from them in 1959. However, one of the 1960 cuttings developed typical leaf curl symptoms in December 1960, and leaf curl virus was readily isolated from leaves showing symptoms.

Another pelargonium plant, infected with leaf curl in 1956, showed no further symptoms of this disease in subsequent years, but only faint chlorotic spots and broken rings on the leaves during the summer months. No virus could be isolated by mechanical inoculations to a range of test plants, but inarch grafts to our indicator clone H5 of pelargonium induced conspicuous red splashes and flecks on the pink flowers. Ungrafted control plants of clone H5 showed no such colour breaking.

(5) *Cucumber mosaic virus in shrubs*

Cucumber mosaic virus was isolated from two bushes of *Romneya Coulteri* obtained from different places. Both plants showed only slight leaf chlorosis and lack of leaf symmetry, although one of the virus isolates severely damaged the standard test plants. Attempts to eliminate the virus by heat treatment failed because the treated *Romneya* plants died.

Cucumber mosaic was also found in a *Leycesteria formosa* plant with slight chlorotic spots and rings on the leaves.

8. CROP PROTECTION

by

W. H. READ

The work of the Department continued on much the same lines as in 1959, but the investigations on the control of Glasshouse Red Spider Mite (*Tetranychus telarius*) have been given much greater priority in view of the difficulties experienced in controlling this pest, particularly on cucumbers, owing to the emergence of strains of mites resistant to acaricides suitable for application to this crop. These investigations on Red Spider control are being undertaken jointly with the Entomology Department, and certain aspects of the work are described in the report of that Department.

Trials to compare the effects of annual treatments of a tomato soil with metham-sodium, chloropicrin and by steaming have been continued. Laboratory investigations to obtain information on the distribution of metham-sodium, its conversion to methyl isothiocyanate, and the distribution and loss of this compound from soils have been continued.

Glasshouse trials have shown that excellent control of Cucumber Powdery Mildew (*Erysiphe cichoracearum*) can be obtained by vaporising small amounts of sulphur nightly. The incompatibility of sulphur with petroleum oils is well-known; consequently it is evident that the use of sulphur to control Powdery Mildew on cucumbers is to some extent dependent on the solution of the problem of controlling resistant strains of Red Spider Mite by means other than petroleum emulsions. As sulphur vaporised in this manner was found in certain trials to control Red Spider Mite, the importance of further work to determine the effect of sulphur vaporisation on cropping and Red Spider control is apparent.

Investigations on the problem of controlling narcissus foliage diseases, and of the factors responsible for damage to narcissus foliage by copper fungicides, have been continued.

Soil sterilisation investigations (J. T. Hughes, W. H. Read and R. J. Smith)

Comparison of metham-sodium, chloropicrin and steam as soil treatments

The trial commenced in 1958 was continued for the second year in houses C1 and C2. The methods of application and amounts of sterilants applied to the plots were as in the previous year, but the plots were planted with two varieties only—'Potentate' and 'Money-maker'.

The treatments, briefly summarized, were:—

- (i) Steaming by the Hoddesdon pipe system.
- (ii) Metham-sodium—a proprietary solution containing 39% w/v of sodium methyldithiocarbamate diluted 200 times and the diluted solution applied as uniformly as possible to the border soil at the rate of $4\frac{1}{2}$ gallons per square yard.

Date of application—14th October.

Surface "sealed" by sprinkling with water (approximately $\frac{1}{2}$ gal./sq. yd.) on 16th October.

- (iii) Chloropicrin—3·5 ml. per injection at 12 in. staggered spacings and to a depth of 6 in. Date of application—5th and 6th November.
Surface “sealed” by treading and sprinkling with water (approximately $\frac{1}{2}$ gal./sq. yd.) immediately after application and again two days later.
- (iv) Control—no soil sterilisation treatment.

The post-sterilisation cultivations were the forking over of the soil of the plots treated with chemicals nine weeks, and again at eleven weeks, after applying the sterilants. The steamed plots were also forked over, just before flooding. All the borders were flooded with approximately 15 gallons of water per square yard on 25th January, and the plants were set out in the borders on 4th March. Normal cultural conditions were given. The fruit from each of the two varieties from each plot was weighed and graded separately.

The mean yields from each treatment are given in Table I, together with those obtained in the 1959 trial.

TABLE I
SOIL STERILISATION EXPERIMENT : MEAN YIELDS PER TREATMENT 1960,
WITH THOSE OF 1959 FOR COMPARISON

Treatment	Yield (lb./plant)		
	1960		1959 All varieties
	‘Potentate’	‘Moneymaker’	
Steam	11·13	11·79	9·75
Chloropicrin	10·93	11·66	9·63
Metham-sodium	10·26	11·28	9·48
Control	6·03	6·58	7·25

The results obtained in the second year of the repeated treatments are very similar to those obtained in the first year, and they indicate that under the conditions of these trials there was no reduction in response to soil treatment with chloropicrin or metham-sodium for the second year when compared with the response to steaming.

The possibility of obtaining a numerical assessment of the relative amounts of clean fibrous root, corky root and rotted root was examined, but further work is necessary before any method based on physical measurements can be adopted. The visual examination of the roots, which were carefully forked out, showed that those from the steamed plots had little “corky” tissue, very little basal rot and a fair to good amount of fibrous root. Those from the plots treated with chloropicrin had slightly more “corky” root and basal rot, and those from the metham-sodium plot were slightly inferior in all respects to those from the chloropicrin-treated plots. Control plants had roots severely affected by “corky” root and basal rot and had very little healthy fibrous root. *Colletotrichum atramentarium* was not in evidence on any roots.

The determination of residues of methyl isothiocyanate in soil

The presence of methyl isothiocyanate in extracts of soil which have been treated with metham-sodium can be demonstrated by plotting U.V. absorption spectra after dilution and the addition of ammonium hydroxide and correction for empirical soil blanks (2). Determinations of methyl isothiocyanate by this method are, however, limited to the relatively large amounts

of the compound present in the soil shortly after treatment with metham-sodium at dosages normally used in soil sterilisation procedures. To determine the amounts of methyl *isothiocyanate* residues remaining in a glasshouse soil at intervals up to ten weeks after treatment with metham-sodium the following method, based on the distillation of methyl *isothiocyanate* from a sample of the soil to which water and ethyl alcohol have been added, was used.

To 10–25 g. of the sieved ($\frac{1}{4}$ in.) sample of the soil in a 250 ml. standard-joint flask are added 100 ml. of water and 5 ml. of ethyl alcohol. The flask is connected by a delivery tube to a small water-cooled condenser, using glass joints throughout. The mixture is gently heated to boiling and slowly distilled, the distillate being collected in a 25 ml. graduated test tube. To the distillate, which should be at least 10 ml. but may be slightly more, are added 10 ml. of 0.880 ammonia solution and the volume made up to 25 ml. with water. The absorbance of the solution is measured at a wavelength of 235 m μ after standing for at least 10 minutes at room temperature. This is the time required to ensure the conversion of the methyl *isothiocyanate* to N-methylthiourea. Good recoveries of added amounts of methyl *isothiocyanate* have been obtained from a range of soils. The blanks obtained with the corresponding soils untreated were low.

The amounts of methyl *isothiocyanate* in the soil are estimated by reference to a calibration curve obtained with solutions of methyl *isothiocyanate* and ammonia. Table II shows the results obtained with known amounts of *isothiocyanate* added to a soil, and Table III the results obtained with soil to which known amounts of metham-sodium have been added. The columns marked (A) show the amounts estimated by reference to known amounts of aqueous N-methylthiourea, and those marked (B) the amounts estimated by reference to known amounts of aqueous methyl *isothiocyanate*.

TABLE II

Methyl <i>isothiocyanate</i> added		Methyl <i>isothiocyanate</i> found (A)		Methyl <i>isothiocyanate</i> found (B)	
<i>p.p.m.</i>	μg	μg	%	μg	%
1.30	32.6	27.6	85	30.1	92
2.17	54.4	50.0	92	54.6	101
3.26	81.5	76.6	94	83.6	102
4.35	108.7	101.3	93	110.6	102
5.43	135.9	130.9	96	143.0	105

TABLE III

Sodium-methyl dithiocarbamate added		Theoretical equivalent of methyl <i>isothiocyanate</i>	Methyl <i>isothiocyanate</i> found (A)		Methyl <i>isothiocyanate</i> found (B)	
<i>p.p.m.</i>	μg	μg	μg	%	μg	%
4.24	106	47.0	38.2	81	41.7	89
8.48	212	94.1	80.7	86	88.2	94
12.8	319	141	116	82	127.1	90
17.0	425	188	147	78	160.3	85
21.2	531	235	199	82	216.8	92

The identity of the U.V. absorbing compound obtained in the tests with soils was shown by plotting several absorption spectra. These were found to correspond with the spectrum of N-methylthiourea.

The method of estimating the amounts of methyl isothiocyanate in soils has been used to study the distribution and loss of this compound in glasshouse border soil treated with metham-sodium. These investigations are being continued in a study of various factors affecting the safer use of soil sterilants based on methyl isothiocyanate or compounds decomposing in soil to produce this compound.

In furtherance of the quest for means of avoiding damage to plants resulting from the presence of very small amounts of methyl isothiocyanate in the soil, which may cause injury to the plants on their release to the glasshouse atmosphere, a sensitive colorimetric chemical test has been devised. The practical value of this test, which is rapid and simple, is being studied since if reliable under the varying conditions encountered on commercial nurseries it will have advantages compared with the use of test plants.

The chemical elimination of methyl isothiocyanate residues

Attempts were made to convert traces of methyl isothiocyanate to the less volatile and apparently less injurious N-methylthiourea by treating the soil with compounds capable of transiently releasing ammonia or temporarily inhibiting the biological nitrification of ammonium compounds. These procedures have certain practical and theoretical difficulties, and preliminary results have not been promising.

Red Spider Mite investigations (W. H. Read and Valerie A. Cooke)

A number of potential acaricides have been tested against a strain of Red Spider highly resistant to organo-phosphorus compounds and slightly resistant to "Kelthane" (1:1-bis *p*-chlorophenyl-2, 2, 2-trichloromethylethanol). The only compound showing merit was one structurally similar to 2:4-dinitrophenyl-6-(1-methyl-*n*-heptyl)-phenyl crotonate, the active principle of "Karathane", the powdery mildew fungicide which also possesses some acaricidal activity. At the effective concentration of 0.015% the experimental material proved too phytotoxic.

Trials were also made with sprays containing emulsified polybutenes of high viscosity (15,000 sec./210°F.) which were shown by Fisher (1) to give good control of Red Spider. The polybutene spray was found slightly phytotoxic to cucumbers at 2.0%, causing yellowing of the edges of older leaves and some reduction in the rate of growth of leaves and lateral shoots. There was no indication of phytotoxicity at 1.0% concentration. Difficulties were encountered because of the high viscosity of this polybutene fraction unless care was taken to thoroughly clean out the sprayer tank, hoses, etc. A series of less viscous grades of polybutene have been obtained, and their relative values for the control of Red Spider on cucumbers will be compared.

The merit of polybutene sprays may be associated with the persistence of their tackiness. Tests showed that cucumber leaves sprayed with 2% polybutene of this viscosity trapped adult female mites for a period of four days following application. At 1.0%, however, some mites placed on the leaves were not trapped and were able to re-infest the plants.

A strain of Red Spider having a resistance factor to parathion of $\times 14$ at L.D.₅₀ when compared with a non-resistant strain, was found to have a resistance of $\times 24$ to paraoxon, from which it may be inferred that the resistance to parathion is not due to a reduction in resistant mites of the ability to convert parathion into the active cholinesterase inhibitor, paraoxon.

Narcissus Leaf Scorch (*Stagonospora curtisii*) (Pauline Smith & R. J. Smith)

In order to develop techniques for the bioassay of chemicals for the control of Narcissus Leaf Scorch (*Stagonospora curtisii*) it has been necessary to study some aspects of the biology of the fungus. Examination of bulbs during the dormant period has shown the presence of the mycelium between the dry papery scales and the outer, fleshy scales (swollen bases of the previous season's leaves) on the following varieties: 'King Alfred', 'Magnificence', 'Soleil d'or', 'St. Agnes', 'Actaea' and 'Cheerfulness'. Work is continuing to determine (1) if this mycelium is definitely the origin of the primary tip infections on the new emerging leaves and the source of some of the infection on older leaves which appears as irregular rust spots and lesions, and (2) if there are varietal differences in susceptibility to primary tip infection. When agar discs of mycelium were placed in contact with emerging leaf tips in the nose of 100 bulbs of each of three varieties, leaf scorch symptoms developed on the foliage tips of 98% of 'Cheerfulness' bulbs, 66% of 'Magnificence' and 15% of 'King Alfred'.

Inoculation of young, green foliage of 'Soleil d'or' by the application of agar discs of mycelium to the abraded leaf tips produced infection symptoms in 98% of the treated tips within seven days. Plants inoculated by this method were used to assay the eradicator efficiency of various fungicides.

Attempts to inoculate young, green foliage of 'Soleil d'or' by spraying with a water suspension of pycnidiospores produced no infection unless the waxy cuticle was first abraded with "Celite" or rubbed with cotton wool moistened with ether to remove the wax. Spore suspensions sprayed on young, *blanched* shoots have produced Narcissus Leaf Scorch symptoms within seven days on all varieties tested: 'King Alfred', 'Magnificence', 'St. Agnes', 'Unsurpassable', 'Actaea', 'Flower Record', 'Sempre Avanti', 'Cheerfulness' and 'Geranium'. Work is in progress to determine the susceptibility of foliage to spore infection at different stages of growth and to correlate this with determinations of the amount of wax present on the leaf surface.

Fungicidal tests

Thirteen chemicals formulated with petroleum oil, Manoxol or polyvinyl acetate have been applied to narcissi with leaf tip infections to determine their eradicator activity. Bordeaux, dichlone, zineb and phenyl mercury acetate were the most promising materials, but none gave complete control; they only delayed the downward spread of the disease from the leaf tips. The addition of petroleum or polyvinyl acetate to fungicidal sprays tended to increase the extent of leaf scorch arising from the initial infection by *Stagonospora* when compared with the same fungicides in sprays containing Manoxol as a wetting agent.

Work is in progress to assay the protectant activity of various fungicides against the secondary infection arising from pycnidiospores produced at the site of the primary infections. The installation of misting equipment has provided more suitable conditions for spore dissemination and germination.

Determinations of the gross amounts of cuticular wax on the leaves of a number of varieties of narcissus indicate that reported susceptibilities to damage by sprays or attack by *Stagonospora* are not due to differences in the amounts of wax. The extent to which the damage, which is particularly severe in the Isles of Scilly, is associated with other factors, including salt laden mist, has been investigated. Experiments have also been made to find out if the damage following the use of Bordeaux sprays can be reduced by spray additives.

Cucumber Mildew control (Pauline Smith)

Experiments with sulphur vaporised nightly in small quantities from an apparatus designed for this purpose showed that Cucumber Mildew (*Erysiphe cichoracearum*) could be controlled effectively by this means. Tests on cucumber plants heavily infected before sulphur vaporisation commenced showed that the nightly vaporisation of sulphur at a rate of 1 oz./50,000 cubic feet protected young foliage from infection and checked the development of the disease on leaves infected before the treatment commenced.

Evidence was obtained that the nightly vaporisation of sulphur at this rate effected a gradual reduction in the number of Red Spider on infested plants. In one trial complete control of this pest was obtained after a period of four weeks.

Sulphur vaporisation was later employed to control Cucumber Mildew on the cucumbers grown in the Institute's commercial-type cucumber houses where routine applications of "Karathane" dusts or sprays prepared from a wettable-powder "Karathane" formulation failed to give adequate control of the disease. So far no trials have been made to determine the effect of sulphur vaporisation in this manner on the cropping of cucumbers, but the procedure does not appear to harden the plants more than routine applications of "Karathane". The action of sulphur on Red Spider Mites is being examined in detail.

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9. HORTICULTURE

by

G. F. SHEARD

The work of the Department has expanded rapidly during the year under review. A good start has been made on problems connected with loamless composts, and in order to make more rapid progress pending the provision of further facilities trials on the planting density of carnations have been carried out on two local nurseries. Following the departmental re-organisation recommended by the A.R.C. Visiting Group, the work on tomato growth control, tomato blotchy ripening, and on the cultural and environmental problems of mushroom production have been integrated into the Horticulture Department's programme. In collaboration with the Chemistry Department work has been started on the nutrition of early flowering chrysanthemums grown outdoors.

Tomato growth studies (A. J. Cooper)

The study of the effect of the time of year and plant age, and their interactions, on the pattern of development of the tomato was continued. This study was begun in 1959 and will be completed in 1961. Sowings have been made at weekly intervals from 22nd September, 1959 to 11th October, 1960, and detailed weekly observations made on the development of the main shoot, leaves, flowers and fruit from germination until each plant is about ten months old. This work is primarily designed to test two hypotheses suggested by earlier work. Firstly, that the growth rate is depressed (a) during the period between the autumnal dawn-to-dusk equinox (13th October) and the shortest day (21st December), (b) following the anthesis of the first inflorescence, and (c) in early May, if germination takes place between the autumnal equinox and the shortest day. Secondly, that once fruiting is well established a constant ratio between leaf area and fruit volume is maintained except during the months of November, December and January.

A test was made of the hypothesis that the reduction of the growth rate in May is related to a supra-optimal day length by growing plants in two partially-controlled environmental chambers using natural daylight as the light source. A previous test made by growing plants in different latitudes (Finland, Clyde Valley, Sutton Bonington, Littlehampton, Guernsey and Malta) suggested that supra-optimal day length was not the cause of the check, and the work in the chambers supports this conclusion. The effect of light duration on tomato development, using natural daylight and reducing the day length by covering the plants with opaque shields, was also investigated. The growth rate was related to the light duration, but declined very rapidly between durations of six and eight hours.

Under conditions of free root run and adequate moisture the development of the first inflorescence is arrested during the period bounded by the autumnal equinox and the shortest day. There is, however, a strong interaction between root restriction and the development of the first truss. A preliminary investigation of this was completed in 1960. A study was also made of the effect of sowing date on early and total yield. During this work the difficulty of interpreting the results of applied work where a treatment increases early yield but decreases subsequent yield became apparent. An attempt was therefore made to develop methods of weighting yield data for market price to give an equivalent market yield. Using these methods the date of sowing trial completed in 1960 suggested that the earlier the sowing date the greater the return, even allowing for increased fuel costs.

Blotchy ripening of tomato fruit (A. J. Cooper)

The first stage of the work at the Lee Valley Experimental Horticulture Station, extending over two years, has been completed. The first year's results have been analysed and show that the proportion of uniformly coloured fruit was significantly affected by the day temperature, the water regime, the variety and the presence of shading on the glasshouse. A day temperature of 65°F., as opposed to 85°F., increased the proportion of uniformly coloured fruit from 33% to 45% of the total; a dry moisture regime, as opposed to a wet regime, increased the proportion from 34% to 44%; and the use of 'Ware Cross', in contrast to 'Potentate', increased the proportion from 34% to 44%. Heavily shading the glasshouses increased the proportion only slightly from 38% in the unshaded to 40% in the shaded areas.

Low temperature reduced the proportion of green-back (grade A) and green blotch (grade C), but increased the proportion of yellow blotch (grade B). The overall increase in uniformly coloured fruit at the lower temperature was due to a decrease in green-back and green blotch despite an increase in yellow blotch.

The absence of shading increased the proportion of green-back and green blotch, but reduced the proportion of yellow blotch and the Z type of disorder. The classification of fruit ripening disorders used is that developed by Cooper in 1958.

Watering had no effect on green blotch over the whole season but significantly reduced the trouble in the early part of the summer (mid-May to mid-July), suggesting that watering had a greater effect on this disorder early in the season. A dry regime reduced the proportion of green-back, yellow blotch and the Z type of disorder. Overall, a dry water regime is associated with a reduction of colour ripening disorders.

The varietal response was very marked, 'Ware Cross' showing a reduction in all types of colour-ripening disorder relative to 'Potentate'.

There were significant interactions between all the environmental factors considered, the most marked being that between shading and temperature.

Water regime did not significantly affect the total yield of fruit. The wet regime increased mean fruit weight by 11% and decreased fruit number by 4%, and thus maintained a total yield not significantly different from the dry regime.

There was no difference in yield between the two varieties. 'Ware Cross' bore 12% more fruit, but the mean weight of 'Potentate' was 10% greater than that of 'Ware Cross'.

Shading and day temperature markedly affected the yield of both varieties. Shading reduced yield by 40% but did not affect mean fruit weight, so the reduction in yield was due to a reduction in fruit number. Low day temperature increased yield by 20%, this being due to an increase in mean fruit size and not to an increase in fruit number.

It is of considerable interest that there were no significant varietal interactions with shading, day temperature or watering in spite of the extreme level of the factors employed, suggesting that 'Potentate' and 'Ware Cross' respond similarly to changes in these factors.

The greatest proportion of uniformly coloured fruit was produced by the variety 'Ware Cross', grown under a dry moisture regime, kept cool by day and shaded. The heaviest yield was given by 'Ware Cross' heavily watered, kept cool by day and unshaded. The difficulty of accurately interpreting such a picture in practical terms again stresses the need for methods of assessing the profitability of the treatments, or the need for parallel economic studies.

The work will be expanded in 1961 to occupy three vinery houses and to include nutrition as an additional factor.

The statistical work on the incidence of fruit ripening disorders, done in collaboration with Mr. J. C. Gower of Rothamsted Experimental Station, was completed in 1960.

Mushrooms (P. B. Flegg)

Trials of the equipment for studying the growth of the mushroom under controlled conditions have been satisfactorily completed in co-operation with Miss Gandy of the Mycology Department. Three experiments were carried out to learn the behaviour of the eight controlled chambers and to determine how best they could be used for environmental studies.

A comparison of the development and yield of the mushroom has been made at 65°F. and 70°F., at "high" (85–100%) and "low" (40–50%) relative humidity, and at ventilation rates from 1 to 10 cu. ft. air per hour per sq. ft. of bed. Because of the small number of replicates possible, large differences in yield are required to obtain significant differences between treatments. It was, however, established that yield was significantly higher at 65°F. compared with 70°F., and at high humidity compared with low. Increasing ventilation rate tended to increase yield, but the differences were not significant at the 5% level of probability.

The investigation of the causes of variability between plots receiving identical treatment and the effect of various cultural practices on yield has been continued in collaboration with D. Cooke of the Statistics Section. It has been established that omitting to trash the beds after picking does not affect yield and reduces the cost of production. The later the stage at which mushrooms are picked, the greater is the yield and the smaller the amount of labour required for picking. Picking at a late stage produces fewer but larger mushrooms compared with picking at the button stage. The choice of the stage at which to pick for maximum cash return depends on the relative prices of the various grades. At the Institute, cups were found to give the highest and buttons the least cash return. Picking in the button stage also involves extra labour charges for picking and packing. The periodicity of flushes was also affected by the stage of picking, and this is being further investigated.

Studies on the growth and development of thickened strands have been continued and, in particular, the effect of the moisture content of the casing layer is being investigated.

The development of techniques for measuring moisture stress in soil, peat and compost, using the Peltier effect, has continued, but the work was held up for a period owing to the re-organisation of the laboratories.

The literature on mushroom composts has been surveyed in preparation for starting work in this field, and a review is published on page 125.

Loamless composts (A. C. Bunt)

Large scale factorial trials have been carried out in the glasshouses to determine the suitability of various materials to replace loam in seed and potting composts. The first objective was to record the growth of several species in a wide range of materials. Peat, sand, vermiculite, perlite and clay have been used in various combinations and ratios. In addition, growth comparisons in sedge and sphagnum peat have been made, and the effect of particle size of both peat and sand investigated.

These experiments have shown that *Antirrhinum* and *Linum* are more sensitive than the tomato to both the physical and chemical properties of the medium. A range of subjects is

now being screened for sensitivity. To date peat/vermiculite mixtures have given the best results, followed by peat/sand. During the period March to October tomatoes grown in these mixtures to the planting out stage have been equal or superior to those in standard loam-based composts. Perlite/sand mixtures have given inferior results in comparison with other loamless mixtures.

Antirrhinum in loamless mixtures has shown a number of growth abnormalities, including leaf distortion, chlorosis and loss of apical dominance. These symptoms were worse in those mixtures in which the peat, vermiculite or sand fractions were "coarse", and least where the fractions were "fine". The quantity of base fertiliser and the ratio of nitrogen to calcium appear to influence these disorders.

Carnation: plant density and date of planting (G. F. Sheard and A. C. Bunt)

Two trials have been conducted on commercial nurseries in the locality on the effect of spacing on the yield and quality of bloom. They were planted in July/August, 1959, and have cropped during 1960; one trial had to be prematurely terminated in May but the other has flowered through the year. The plant density varied from 15.3 to 31.0 square inches per plant in one trial, and from 21 to 63 square inches per plant in the other.

To extend this work a combined plant density and time of planting trial has been started at the Institute. The trial is laid out as a 4 × 4 Latin square with planting dates in July 1960, September 1960, January 1961, and March 1961, and with plant densities of 21, 35, 49 and 63 square inches per plant.

The July planting began to flower in November, and the yield per unit area of bed after two months was not significantly different for the four densities. This result is in agreement with the two trials on commercial holdings where, again, there was no effect on the early yield. Subsequently in the commercial trials the high density treatments have tended to give a higher aggregate yield. The quality of the blooms, assessed by a visual grading system, has been affected by the planting density. The low density treatments have given better quality blooms (Table I), but in one trial (Table II) the percentage of split blooms has increased with decreasing plant density.

TABLE I
THE EFFECT OF PLANT DENSITY ON THE YIELD
AND QUALITY OF CARNATION BLOOMS, VARIETY
'WHITE SIM', PLANTED JULY, 1959

	Spacing (sq.in./plant)			Remarks
	21	42	63	
Blooms/sq. ft.	16.6	11.8	11.0	Cropping Jan.—May 1960
Blooms in top two grades (%)	29	36	37	

TABLE II
THE EFFECT OF PLANT DENSITY ON THE YIELD
AND QUALITY OF CARNATION BLOOMS, VARIETY
'PINK SIM', PLANTED AUGUST, 1959

	Spacing (sq.in./plant)				Remarks
	15½	18½	23	31	
Blooms/sq. ft.	38.2	36.8	36.7	34.7	Cropping March—Oct. 1960
Split blooms (%)	15.5	15.8	17.8	20.9	

Chrysanthemum manurial trial (G. F. Sheard and A. C. Bunt in collaboration with G. W. Winsor and M. I. E. Long, Chemistry Dept.)

A long term factorial trial using three levels of dung (0, 30, 60 ton/acre), nitrogen (0, $7\frac{1}{2}$, 15 cwt./acre nitro-chalk), potash (0, 4, 8 cwt./acre sulphate of potash) and phosphate (0, $7\frac{1}{2}$, 15 cwt./acre superphosphate) was started in 1960. A preliminary examination of the first year's results shows that the crop responded to little but nitrogen. Nitrogen and dung advanced the median cutting date and increased flower diameter and stem length.

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III. SPECIAL RESEARCH REPORTS AND REVIEWS

1. THE SPECIFIC STATUS OF SOME EUROPEAN STRAINS OF THE GLASSHOUSE RED SPIDER MITE

by

W. J. PARR and N. W. HUSSEY

Introduction

Until recently all specific determinations within the family Tetranychidae were made solely on morphological characters, but as many species differ only in minute detail the resultant nomenclature was confused. Pritchard and Baker (6), for instance, listed 58 synonyms of the Glasshouse Red Spider Mite *Tetranychus urticae* Koch (= *T. telarius* L). Boudreaux (1) made a notable advance by utilising mating experiments to demonstrate specific differences between *T. telarius*, *T. cinnabarinus* Bois and *T. lobosus* Boudreaux. Dillon (3) tested sixteen geographic strains of the *T. telarius* complex by similar techniques, and concluded that the green forms in Europe were distinct from those in America which he proposed should be named *T. bimaculatus* Harvey. These studies suggested that a complex of strains existed within populations of greenhouse mites and, in view of the necessity for future work on the inheritance of acaricidal resistance, breeding studies were begun at this Institute to determine the specific status of European populations.

In a series of papers Hussey and Parr (4, 5) and Bund and Helle (2) confirmed American opinion that there are two distinct species of spider mites in glasshouses—*T. cinnabarinus* with reddish-brown summer females and *T. urticae* in which the females are green. The former species does not diapause and is therefore normally associated with perennial hosts such as carnations. Parr and Hussey (5) also showed that the British and American strains of *T. urticae* will interbreed normally so that the American name *bimaculatus* should be regarded as a synonym of *urticae*. It should be emphasised here that European acarologists adopted the specific name *urticae*, in preference to *telarius*, at the Symposium on Acarology held at East Mallang in 1959.

Dillon (3) presented evidence of a lack of compatibility between strains from Germany and Southern England, but in the light of Boudreaux' more recent work (*in litt.*) it is possible for such apparently incompatible strains to be conspecific. His data show that two local populations can be less compatible with each other than either of them with a third strain from another continent.

The present breeding programme was undertaken to establish the relationship between the British strains and those from Europe recently studied by Bund and Helle.

Experimental procedure

To ensure that no prior fertilisation had occurred female resting deutonymphs of the respective strains were isolated on leaf discs. These discs were floated on nutrient solution at constant temperature, and the females subsequently allowed to mate with their own sons to initiate pure inbred lines. Each interstrain cross between a male and female was made by isolating the pairs on separate discs. The material tested came from inbred stocks of *cinnabarinus* and *urticae* maintained at this Institute and at Aalsmeer in Holland.

TABLE
PROGENY OF CROSSES BETWEEN CONTINENTAL AND
BRITISH STRAINS OF GLASSHOUSE RED SPIDER MITE

Cross	No. of pairs	Eggs				Adults maturing (sample)		Sex Ratio ♀ : ♂
		Total	Mean/♀	♀/Day	Viability (%)	♀	♂	
<i>T. urticae</i> Aalsmeer ♀ × <i>T. urticae</i> G.C.R.I. ♂	5 6	184 381	37 63	7.1 8.2	83 70	33 82	7 13	5 : 1 6 : 1
<i>T. cinnabarinus</i> Aalsmeer ♀ × <i>T. cinnabarinus</i> G.C.R.I. ♂	5 7	257 259	51 37	7.6 7.4	90 95	74 81	15 40	5 : 1 2 : 1
<i>T. cinnabarinus</i> G.C.R.I. ♀ × <i>T. cinnabarinus</i> San Remo (Italy) ♂	5 7	239 340	48 49	7.7 7.0	88 90	54 107	18 62	3 : 1 2 : 1

Results

The breeding tests showed that all the strains were inter-fertile, and each gave sex-ratios which suggested normal fertilisation of the females (see Table). The fecundity of the females was similar to that expected from normal inbred lines. The normal behaviour of both continental strains of *cinnabarinus* when crossed with the British strain was emphasised by evidence from Helle (*in litt.*) that he had made normal fertile crosses between the Aalsmeer and San Remo strains.

Conclusions

The difficulties which were anticipated a few years ago in defining the specific status of various strains of the Glasshouse Red Spider Mite have now been shown to have been exaggerated. In fact there are only two distinct species, *T. cinnabarinus* and *T. urticae*, which occur throughout Europe and America. The natural ranges of these species are restricted by differences in diapause habit, but they often occur together in the artificial environment afforded by glasshouses.

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2. CARNATION ETCHED RING: A PRELIMINARY REPORT ON AN UNDESCRIBED DISEASE

by

M. HOLLINGS and OLWEN M. STONE

Conspicuous chlorotic spots, flecks and rings, similar to those caused by carnation ringspot virus, were seen on the younger leaves of carnation plants of the variety 'Cocomo Sim' but, although mottle virus was present, ringspot virus could not be detected by inoculation or serological tests. Inarch "bottle-grafts" from affected plants to other Sim varieties and to 'Joker', already infected with mottle virus, induced the additional leaf symptoms after three months (see Plate 1). After a further four to six weeks, whitish etched necrotic flecks and rings, usually oval or dumb-bell in shape, appeared on the middle leaves of grafted plants. These necrotic symptoms also developed in the original 'Cocomo Sim' plants, and have been seen in several other varieties, both naturally-infected and after graft-inoculation. Because these necrotic symptoms appeared to be characteristic of the disease, and sufficiently distinctive for diagnosis, the name "etched ring" seemed appropriate. Small, irregular rings and streaks also developed on the stems of several infected varieties, though less frequently than on the leaves (see Plate 3). Ungrafted control plants did not develop any of these symptoms.

Typical symptoms of etched ring were also seen by one of us (M.H.) in carnation stocks in the United States, especially in varieties that were badly affected in England; the symptoms were quite distinct from those of carnation streak, which occurs in the United States.

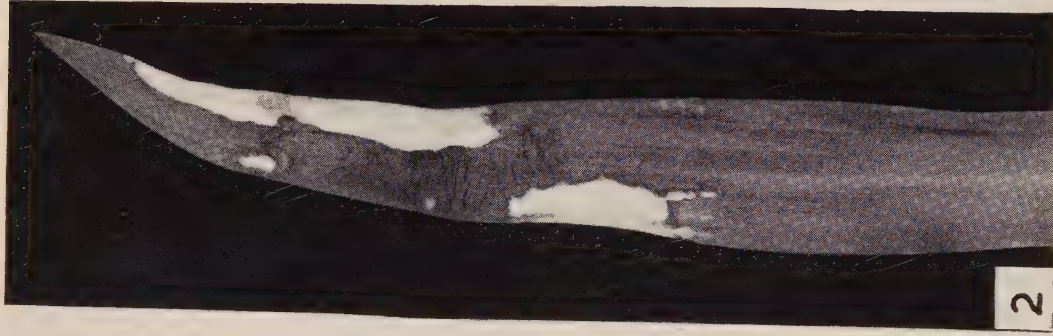
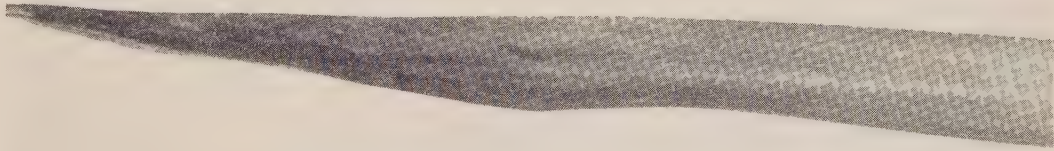
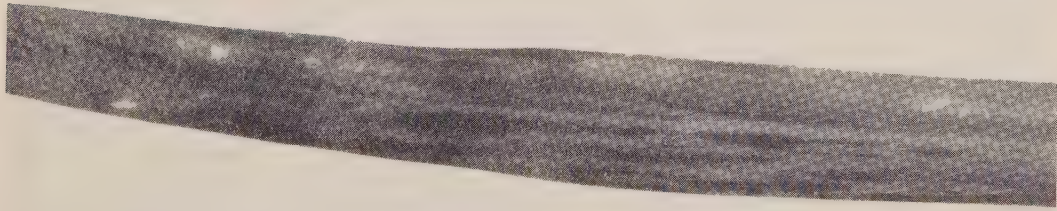
All plants of the varieties 'Harvest Moon', 'Cocomo Sim' and 'Peppermint Sim' that we have examined have shown symptoms of etched ring, but some commercial stocks of 'Joker', 'Picotee', 'Saugus White', 'Arthur Sim', 'Pink Sim', 'Salmon Sim', 'Tangerine Sim', 'White Sim' and 'William Sim' varieties have contained fewer than 65% of plants visibly affected. Symptoms are more severe in some varieties than others, and are sometimes masked when the plants are growing slowly, but cuttings taken from affected plants always developed typical symptoms. Of the varieties tested so far, 'Joker' has shown the most severe and conspicuous symptoms, and is currently being used as an indicator.

Some plants of variety 'Joker' showing symptoms of mottle and etched ring also had conspicuous necrotic blotches of irregular shape, usually pale fawn in colour with darker brown or maroon edges, on the leaves. Grafts from these plants to 'Joker' plants believed to contain only mottle virus induced the appearance of this "Joker blotch" symptom (see Plate 2). Whether this is due to a severe form of etched ring, or represents a separate disease, is not yet known.

The chlorotic rings have developed in grafted 'Joker' plants in as little as three weeks, but the appearance of the etched rings usually followed a check to vegetative growth, such as the initiation of flower buds. Necrotic rings have also appeared on the leaves of two clones of Chabaud seedlings grafted with 'Cocomo Sim', but seedlings have generally given a less distinct reaction than either Sim varieties or 'Joker'.

The extent of damage to the flowers is uncertain; compared with control plants infected with mottle virus, flowers on plants with mottle plus etched ring have had more colour breaking, untidiness and sometimes distortion of the petals.

CARNATION ETCHED RING



1. Initial symptoms of carnation etched ring in var. 'Joker'; chlorotic rings on the leaves, and necrotic rings developing.
2. Characteristic "Joker blotch" symptom; pale, necrotic blotches in leaves of var. 'Joker'.
3. Necrotic etched rings in stems of var. 'Red Sim'.

We have so far been unable to transmit etched ring by sap inoculation, either from carnation to carnation or to fifteen species of test plant that react with one or more of the carnation viruses. Inoculations have mainly been to plants known to be little affected by the inhibitors present in carnation sap, but so far the only symptoms produced have been those associated with mottle virus.

Aphid transfers from affected 'Cocomo Sim' plants to 'Joker' carnations, using both *Myzus persicae* (Sulz.) and a carnation aphid believed to be *M. dianthi* Schrank, failed to cause infection, whether short acquisition and test feeds (2—5 min.), or longer feeds of up to seven days, were given.

Only "spherical" particles of the kind associated with mottle virus were found in electron micrograms of preparations (including butanol-chloroform extracts) from affected and unaffected plants of variety 'Joker'.

Density gradient centrifugation tests, to compare preparations from carnations containing mottle and etched ring with those believed to contain mottle only, and with those from healthy plants, have given inconsistent results. In some there was a visible zone in tubes containing mottle plus etched ring that was not present in tubes containing mottle virus only; but when this zone was extracted, tests for infectivity, serological activity and presence of particles revealed only mottle virus in low concentration.

In an attempt to eliminate mottle, affected 'Cocomo Sim' scions were grafted to a clone of *Dianthus barbatus* L. (sweet-william) that is resistant to mottle virus. The sweet-william stocks were checked at monthly intervals by serological means and by inoculation to *Chenopodium amaranticolor*, and one *D. barbatus*, which consistently gave negative reactions in these tests for mottle, was grafted to seedling Chabaud carnations. None of the Chabaud plants developed any symptoms of etched ring, though two of them produced faint chlorotic rings and flecks typical of mottle, and mottle virus was confirmed serologically in them. This suggests that the clone of *D. barbatus* used supports mottle virus in a concentration too low to be detected by inoculation or serological methods, but nevertheless capable of infecting Chabaud seedlings when grafted to them. Etched ring appears unable to infect this clone of *D. barbatus*, and has failed to produce symptoms on any *D. barbatus* tested.

Although no specific particles have yet been seen, nor any method of transmission been found that would specifically indicate a virus disease, the available evidence strongly suggests that etched ring is a virus disease whose prevalence and severity of symptoms warrant further study.

3. THE EPIDEMIOLOGY OF TOMATO MOSAIC:

A REVIEW OF THE LITERATURE

by

L. BROADBENT

Tomato mosaic, caused by tobacco mosaic virus (TMV), is widespread in most British tomato crops, especially under glass, and apparently causes considerable losses each year. Its epidemiology, or more strictly epiphytology, is being studied at this Institute to find out how, when and where the disease occurs, what losses it causes, and what can be done to remedy the trouble.

Virus sources and transmission

Seed transmission

There has been controversy over seed transmission of TMV for nearly half a century. In 1915 Allard concluded that TMV does not enter the embryo because seed transmission in tobacco does not occur, and in 1916 he could find no evidence of its transmission through tomato seed. A similar conclusion was reached by Gardner and Kendrick (1922), Caldwell (1934), Jones and Burnett (1935) and Nitzany (1960), who between them grew many thousands of healthy tomato seedlings from seeds from infected fruits.

The early workers who dissected seeds or germinating seedlings and claimed that virus was in the embryo (Bewley and Corbett, 1930; Berkeley and Madden, 1932) or only in the testa (Ainsworth, 1934a) all used relatively few without adequate controls. More recent work by Crowley (1957a, 1958), who dissected 2,000 tomato seeds, has confirmed that by Ainsworth. Crowley considered that seedlings were contaminated from the testa during germination and obtained (1958) 18% of infected seedlings when freshly harvested, uncleaned seeds were sown. Norton and Heuberger (1933) reported that not only was virus absent from the embryo, but seedlings could not be infected prior to the appearance of green colour. Selman (1943a) claimed that in some circumstances, associated either with malnutrition or incomplete maturation of the seed, TMV may be present in the embryo, but his evidence was inadequate. Doolittle and Beecher (1937, 1942) found that 3—4% of transplanted seedlings from seeds planted immediately after harvest without washing, or washed and then dried for eight days, showed mosaic following cotyledon deformity, but that seedlings from seeds stored for 1—12 months showed no symptoms. Fry and McCallum (1960) and Crowley (*loc. cit.*) also obtained a few infected plants from uncleaned seeds left undisturbed after planting, but seeds are not used commercially without being cleaned by fermentation or some other method, so infections obtained from uncleaned seeds have little bearing on the problem.

Raychaudhuri (1952) found that ordinary tomato TMV could be washed from the outsides of seeds for two but not three weeks, after they had been fermented, washed and dried. When germinating seedlings were ground up and inoculated to *Nicotiana glutinosa*, ordinary TMV was demonstrated in seeds up to four weeks old, but another strain of TMV survived in stored seeds for only one week. He suggested that seed transmission depended on the strain of virus, and produced evidence that germinating tomato seeds contained substances that inhibited TMV, inhibitors that differed with tomato variety. However, Crowley (1957b) grew tomato embryos in media containing virus but found no evidence of inactivation.

Milbrath (1937) grew many thousands of tomato seedlings of different varieties, taking great care to prevent contamination, but only in one selection of one variety did he have young

infected seedlings that suggested seed transmission; some seed of this variety was nine months old. Summing up a lifetime's experience, Doolittle (1948) stated that in commercial practice, where seed has been dried for some time before planting, there is little if any seed transmission of the virus. This view is held also by Dr. K. M. Smith and Dr. R. Markham (personal communications), who have grown many hundreds of tomatoes of several varieties from seeds from infected fruits over the last twenty years but have had no indication of seed transmission.

On the other hand, several plant pathologists and perhaps most growers consider that seed transmission is common. Bewley and Corbett (1930) argued that the early appearance of mosaic indicated seed transmission, and that healthy crops can be obtained when "clean", uninfected seeds are used.

Certainly TMV persists in or on the seed testas for a long time after harvest; Milinko (1956) reported at least 400 days, and John and Sova (1955) detected it during 1953 in seed harvested during 1950 and stored in bulk in bags, whereas small samples stored in paper envelopes lost infectivity within seven months, possibly because of greater exposure to air. Nitzany (1960), however, found that seeds in paper bags remained infective for at least eight months.

Several workers have attributed symptoms which appeared late to seed transmission, assuming either that the virus remained inactive in the roots of the plant for several weeks before multiplying and entering stems and leaves, or that there was a long incubation period for a trace of inoculum. For instance, Berkeley and Madden (1932) stated that symptoms were often not apparent until the second truss formed and argued that this late appearance might account for the negative results of other workers with seed transmission; Selman (1943a) suggested delayed seed transmission when some plants first showed infection as the third, fifth or sixth trusses were blooming, and Howles (1952) stated that seed transmission was responsible for infections showing at the third truss stage. While evidence quoted in the section on soil transmission makes it possible that TMV, penetrating through the roots, may sometimes make slow progress to the tops or even remain inactive in the roots of older plants, such occasions are probably rare in young plants; the virus is so very infectious and it would be more logical to attribute late appearance of symptoms to late contamination. Caldwell (1934) could find no evidence for delay in symptom expression in infected young plants, and plants infected through very young primary roots soon became systemically diseased. Most workers have relied on visual symptoms in the tomato as evidence of infection; few have tested roots as well as shoots to find out if virus is present but not causing visual symptoms in shoots.

Whatever the mechanism of infection, practical experience suggests that infected seedlings occasionally develop from infected seed. The difference of opinion that exists may have arisen because of different practices, for a plant pathologist would probably sow seed and leave the plants for a few weeks to see if they became infected, whereas a grower would probably prick out or transplant in the seedling stage. The disturbance of the young seedling a few days after germination may bring it into contact with the infected testa and sometimes cause infection. A field of tomatoes sown directly contained only five infected plants in contrast to 71% in another to which plants were transplanted; presumably the high figure is partly due to secondary spread of virus (Gol'din and Yurchenko, 1958).

The methods adopted in their experiments are not always clearly stated by the authors. However, Chamberlain (1937), after obtaining some "seed transmission" of TMV with tobacco, tomato and black nightshade, stated that as the seedlings were pricked out the results were not convincing proof of such transmission, for contamination might have occurred. It should be possible to find out by careful experiments if seed transmission of TMV is due to contamination of the seedling from the testa at pricking out.

Seed treatments

It is now usually accepted that TMV is on or in the testa, and several attempts have been made to inactivate the virus by chemical or other means. Crowley (1957a, 1958) found that superficial virus was inactivated without affecting TMV in the tissues by soaking seed in a 10% solution of "Teepol" for several hours, after which 35% of testas were still infected. Hydrochloric acid has been used for many years in New Zealand to clean seed (25ml. of commercial HCl added to pulp from 5 lb. of fruit, stirred every half hour for 2 or 3 hours, washed in water and dried), and Chamberlain (1947), Chamberlain and Fry (1950) and Fry and McCallum (1960) found that seeds cleaned by this method or by fermentation gave uninfected plants, whereas uncleaned seeds produced a few infected seedlings. Inoculation of ground seeds to test plants showed that fermentation decreased the amount of virus, whereas acid removed it or decreased it to a very low concentration. This, they suggested, showed that virus was carried on the outside of the seeds, a view held by Canova (1957) who claimed that TMV is completely destroyed by 24 hours' immersion in 6% hydrochloric acid; also that the incidence of seed infection is decreased by washing seeds in running water for two hours or by fermentation. Although Alexander (1960) confirmed the New Zealand work, Crowley (1958) considered acid extraction was not a reliable way of obtaining clean seed because virus is not only a superficial contaminant but is also within the testa. The effectiveness of "acidification" apparently depends upon the temperature at which it is done, most TMV being inactivated at 30°C. but not at 23°C. (Nitzany, 1960). Howles (1957) also was unable to confirm that hydrochloric acid rids seeds of virus, but found that soaking seeds in saturated 2-chlorophenoxyacetic acid for six days, until they were almost germinating, decreased virus to a very low concentration, and if the seeds were then dried and later allowed to germinate in water, no virus could be detected. However, such a treatment is unlikely to be of practical value. Earlier (1952) he had decreased the virus concentration considerably by heating seeds in an oven at 60°C. for 22 days. John and Sova (1955) stated that soaking seeds for fifteen minutes in a 10% solution of tri-sodium orthophosphate inactivated the virus, and Milinko (1956) claimed that soaking for ten minutes in a 1.5–2% solution of sodium hydroxide inactivated it so that treated seeds gave healthy plants, whereas untreated ones gave 33% infected plants, a higher percentage of seed transmission than anyone else has claimed. Alexander (1960) found that soaking seeds in 10% tri-sodium orthophosphate for 30 minutes decreased virus concentration, but did not eliminate TMV; several commercial detergents also decreased virus but only those containing tri-sodium orthophosphate were as effective as this chemical alone. Clearly, more detailed work is needed on this subject to find out which treatment is most efficient.

Soil transmission

The term "soil transmission" covers several possible ways in which the plant can become infected, but mainly (1) by the roots coming into contact with infected plant roots or debris in the soil, or TMV freed from them, or (2) by the lower stem or leaves touching infected soil or debris.

Allard (1917) stated that tobacco plants were infected by transplanting them into infected soil because of damage to the roots, whereas if they were transplanted into a layer of clean soil above the infected soil they usually remained healthy. An experiment to test this does not appear to have been done with tomatoes.

Doolittle (1928) found that TMV remained active in glasshouse soils in the U.S.A. for at least 70 days, and tomato plants were infected when planted into soils that had carried infected crops, but not when planted into uninfected soils. Soil conditions affect virus survival, TMV

remaining active longer in heavy soils than in light, well-aerated ones (Johnson and Ogden, 1929). Powdered infective leaves, however, lost infectivity in less than a month in moist soil, but remained infective for two years in dry, whereas virus remained active in root debris for six months, even in moist soil. These authors confirmed that seedlings were readily infected by planting them into infected glasshouse soil. Tomatoes planted under glass within five weeks of clearing infected plants became infected, whereas those planted after other crops had been grown for six months between tomato crops remained healthy (Jones and Burnett, 1935).

Hoggan and Johnson (1936) investigated virus survival in soil in greater detail. Free TMV was inactivated more rapidly in dry, aerated soils than in moist ones, but not when in plant tissues, confirming the earlier work. TMV was leached out of tissues and carried through soil by water. There was a gradual decrease in concentration of virus recovered after plant debris was buried, but virus could be recovered after eight months. Virus extract itself persisted in moist, poorly aerated soils at moderate temperatures for over twelve months. In Canada, over-wintering of TMV outside differed in dissimilar soils, and inactivation was more rapid outside than under glass (Berkeley, 1942).

Some American workers considered that tobacco plant debris from the previous crop in soil was of little importance (Valleau and Johnson, 1937), but others continued to produce evidence that it could be. Thus Johnson (1937) found an average of fifteen times more infections when tobacco was grown in infected than in uninfected soil, and showed that free virus leached into soil could remain active for one to two years if not dried or frozen. Like Valleau and Johnson, he found that buried debris often failed to infect but that on the surface did, possibly by stem or leaf contact. With one type of tobacco a necrotic reaction showed that transplanted seedlings were often infected through stem or leaves by direct contact or by soil on workers' hands. Berkeley (1942) found that tobacco plants were not infected in seedbeds containing infected debris, except when weeding was done. In a recent paper from South Africa, Bruyns-Haylett (1959) considered that very few plants are infected from debris in soil and that root infection is of minor importance. However, in view of all the evidence to the contrary it must be concluded that infection from soil can and does occur, and as spread within the crop is so rapid during cultural operations, any source of virus must be regarded as important.

It is apparently more difficult to infect tobacco plants with TMV through roots than through leaves. Mulvania (1930) attempted to infect young tobacco seedlings with TMV by applying juice to uninjured roots and to freshly cut roots, or by needle inoculation into them. He obtained no leaf symptoms, whereas leaf inoculation infected 80—90%, but apparently he did not test the roots to find out if they were infected. Repeated attempts by Johnson (1937) to infect tobacco plants through roots also failed to cause systemic infection. Fulton (1941) readily infected tomato roots by direct inoculation, but whereas plants inoculated through leaves showed symptoms in ten days, no leaf symptoms had developed in root-inoculated plants in 28 days. Roots of tomatoes planted into composted infected tomato debris became infected, but virus did not become systemic (Lawrence, 1946). Perhaps the age of the plant is important because tomato seedlings inoculated in very young roots became systemically diseased (Caldwell, 1934).

The most detailed work on this subject was done by Roberts (1950). Different solutions of infective sap were poured on soil around potted tomatoes 4—6 in. high, precautions being taken to prevent sap coming into contact with stems or leaves. In spring a few plants, and in summer most, became infected systemically, but during the autumn virus remained in the roots of most plants, despite pruning the tops after 18 days in an attempt to encourage virus to move upwards. When roots were inoculated in winter and the plants repotted, three of eight inoculated in

fibrous roots, and six of eight inoculated in the tap root, showed virus in the tops five weeks later, but all the roots were infected. When these tests were repeated in spring with plants in the first truss stage, five of six plants became systemically infected. Roberts concluded that virus is sometimes localized around the initial entry point, at other times it may remain in the roots for some weeks before entering stems. Systemic invasion varies with time of year and with individual plants.

The sudden appearance of mosaic symptoms often reported by growers of early-planted hot-house tomatoes during early May might in some instances be caused by the translocation of virus to the tops from roots infected during the late winter, because growth is usually very rapid during late April, or because the plants receive a check (Cooper, 1958b) which somehow aggravates symptom appearance. It is probably more often due to spread within the crop from a few sources during tying and side-shooting which has to be done fairly frequently during this period of rapid growth. More evidence is needed on the frequency with which glasshouse tomatoes are infected from the soil.

As plants can be infected by transplanting them into infected soil it is logical to assume that they would also be if planted out to replace infected plants recently removed. Chamberlain (1937) proved this to be so in New Zealand; 18 of 129 tobacco plants which replaced infected ones showed disease after four weeks, 93 after nine weeks, whereas only one of 109 plants which replaced healthy plants became infected. Similar results were obtained in Canada, about 31% and 2% of plants replacing infected and healthy ones respectively becoming infected (Berkeley, 1942).

TMV in soil and in plant debris can be destroyed by steaming. Virus in undiluted tobacco sap is inactivated in ten minutes at 93°C. or in 80 minutes at 90°C. (Price, 1933), but in dried leaves it may survive higher temperatures (Bartels, 1955). Under glass, 54 of 130 tomato seedlings planted into infected soil were infected, but only one of 130 in infected soil after steaming and one of 70 in steamed uninfected soil (Johnson and Ogden, 1929). Bewley and Corbett (1930) recommended sterilisation by formaldehyde or steaming to prevent infection from soil, but no experiments to test formaldehyde were described. Formaldehyde (2%) inactivated purified TMV in laboratory tests (Kassanis and Kleczkowski, 1944), but Limasset (1957) found 3% and 6% formalin unsuccessful in preventing tomato seedlings from acquiring TMV from debris-containing soil, although no seedling in soil autoclaved at 95°C. for 20 minutes was infected. Johnson and Chapman (1958) tried the effect of several soil fumigants on the roots of TMV-infected tomatoes, treating them for 48 hours in closed containers; only methyl bromide destroyed all the TMV. Selman (1943b) considered such sterilisation was successful mainly because it aided the development of vigorous strong-rooting plants which may resist chance infection, but this is another opinion that awaits experimental confirmation.

Contact transmission

(a) *Handling.* Spread of TMV in tomato crops through handling the plants is self-evident to every worker, and many growers delay the spread of the virus by handling last all plants that are obviously infected and those next to them. Chamberlain (1934) infected seven of 18 plants by handling them after diseased plants, in contrast to none of 24 plants when hands and pruning knife were washed in between. Indiscriminate topping of tobacco plants increased disease incidence from 10% to 41% and 62%, whereas increases were only from 10% to 17% and 12% when healthy plants were topped before handling diseased ones (Lehman, 1934). TMV was transmitted from tobacco to tobacco at sap dilution in water of 1 : 1 million, demonstrating how little is necessary to contaminate the hands (Chamberlain, 1937). The importance

of handling was stressed by Doolittle (1948) who stated that tomato plants grown in fields by direct planting of seed were seldom infected until they were quite old, and he attributed most infections in tomato seedlings to handling by smokers. Most workers have considered that washing hands with soap and water will remove virus, but Berkeley (1942) stressed that running water is essential and that washing in a pail may be ineffective. He found that washing in a solution of tri-sodium orthophosphate is usually effective.

(b) *Smoking tobacco.* The relative importance of smoking tobacco as a source of TMV in tomato crops is almost as controversial a subject as seed transmission. Many tests have proved that TMV occurs in cigarettes, cigars and pipe tobaccos; the virus is remarkably persistent, and tobacco leaves stored in closed jars have remained infective for up to 31 years (Valleau and Johnson, 1927a). These workers, Ainsworth (1935), Chamberlain (1937) and several others in different parts of the world found most commercial brands of smoking tobacco that they tested were infected. Not all smoking tobacco prepared from infected leaves is infective, however, for the temperature reached in flue-curing often destroys the virus (Busch and Wolf, 1933). The practice of chewing tobacco has now died out in many areas; in the U.S.A. much evidence was accumulated that this habit, especially chewing barn-cured tobacco, was responsible for initial infection of many tobacco and tomato crops, through the infective saliva on the hands. Valleau and Johnson (1937) found that manufactured tobacco was less infective because of glycerine and other materials added, heating during manufacture and the presence of the paper around cigarettes. The long incubation period of TMV in tomatoes infected from smoking tobacco and the small proportion of plants infected suggested to Ainsworth (1935) that the virus was present in the tobacco only in low concentration.

Some workers have concluded that tobacco is a common source, if not the main one, of TMV in tomato crops (Jones and Burnett, 1935; Doolittle, 1948; Bewley, 1956; Harrison, 1960), and Howles (1950) stated that where non-smokers only were employed, tomatoes grown from virus-free seed remained healthy throughout the season. In Howles' tests, 15 of 19 samples of tobacco dust from nursery workers' pockets contained TMV and most workers kept their pruning knives in such pockets. Limasset (1957) was able to infect four of 21 tobacco plants handled consecutively after manipulating infected pipe tobacco for one minute.

Other workers, such as Selman (1943b), considered the importance of smoking tobacco had been overstressed, although he recommended that smoking be forbidden to workers when handling plants. Experiments by Johnson (1937) showed that smokers might infect a few plants when transplanting tobacco, but Fukushi (1931) found that whereas tobacco was susceptible to TMV from pipe tobaccos, young tomato plants were resistant. Clinch (1941) and Chamberlain (1947) also doubted if smoking tobacco could be a source of tomato single virus streak, as streak virus is necrotic and may be lethal in many tobaccos. Chamberlain stated that "tomato mosaic" is invariably present in smoking tobacco, but surveys to assess the prevalence of different strains of TMV in tobacco and tomato crops and the extent to which the same ones occur in both, have been few and the samples small (see p. 104).

(c) *Other sources.* Infected plants, infected soil and debris, and tobacco are the sources that have received most attention, but several other possible means of carry-over from one crop to another warrant attention. Considerable emphasis has been placed on washing of hands, but very little attention has been paid to the persistence of TMV on clothes and structures. Johnson and Ogden (1929) found that cloth and board soaked in infected tobacco sap remained infective for two years, both indoors and outside under shelter. Clothing is so readily contaminated by brushing against infected plants that workers must often transmit virus as they move through crops, even if not handling plants, and infective outer garments may well be one

means of carrying virus into newly planted crops. In tobacco crops, Lehman (1934) found that passage of implements increased incidence of mosaic from 5 to 64% in two cultivations and to 81% in four.

Although it is often taken for granted that TMV can survive between crops on glasshouse structures, little experimental evidence has been published. In one test, in 1951, the wiring of two houses which had carried infected crops during the summer was swabbed down with cotton wool at the end of November; the wool from one house was infected but that from the other, which had been washed down with formaldehyde solution, was not. Freedom from TMV was attributed to the washing rather than to chemical inactivation (Dr. R. E. Taylor and Dr. R. Markham, personal communications).

TMV occurs in several weeds, but whether they are sources of virus in tomato crops has seldom been determined. Gardner and Kendrick (1922) found the virus in several solanaceous weeds in Indiana, persisting overwinter in rootstocks of *Physalis subglabrata*, especially when the weeds grew in tomato fields. In 1923 they reported that when this weed was removed from within and around two tomato fields, mosaic reached 0.4% and 1.8%, whereas in a third field left unweeded its incidence was 14.2%. On the contrary, although TMV was found in many solanaceous weeds near tobacco seedbeds, no diseased seedling was seen during six years (Valleau and Johnson, 1927b). Holmes (1941) described a distinctive strain of TMV from *Plantago* which remained localised in tomato or occasionally became systemic with symptoms less obvious than common mosaic. This virus is common in Kentucky, and Valleau and Johnson (1943) suggested that "ordinary" TMV may have been derived from it, for the virus is more likely to have arisen in weeds than in a cultivated annual crop. Holmes (1950) found many strains of TMV in plantains, but their incidence was low, although they spread rapidly in tomato crops in New Jersey when these were infected. A similar strain of TMV was widespread in *Plantago* in Scotland, but plantains were seldom systemically infected by the common tomato and tobacco strains of TMV (Harrison, 1956). In England, Caldwell (1934) considered weeds were probably important as sources of TMV for tomato crops and isolated a strain similar to streak virus from nettles and horse-radish.

Insect transmission

It is now generally accepted that TMV is not transmitted by sucking insects, though it may be occasionally by biting ones. However, some of the earlier papers which stated that aphids were vectors appear difficult to refute and the work warrants retesting. In some instances the plants may have been infected with another virus, such as cucumber mosaic, but this is unlikely in Allard's (1917) experiments, where he found *Myzus persicae* (Sulzer) from cabbage and other common hosts failed to transmit, but those reared on infected tobacco plants did so. He transferred aphids from plant to plant with a brush, and might have transferred virus also by this means, but this is unlikely as other species treated similarly did not transmit. Spread by brush possibly accounts for Gigante's (1938) claim that *Macrosiphum "gei"*, found naturally infesting infected tobacco, infected every tomato and pepper plant to which they were transferred; there is no mention of controls. Bewley (1923) reported transmission by rose aphids and white flies but his experiments lacked controls and replication. Cleveland (1931) reported transmission by *M. persicae* in each of five experiments, and his controls remained healthy, but Fukushi (1931) and Chamberlain (1937) were unable to obtain transmission with *M. persicae*. In addition to stating that *M. persicae* was responsible for at least 50% of the spread of TMV in field tomatoes in Indiana, Cleveland also wrote that *Empoasca fabae* Harr., *Epitrix cucumeris* Harr., *Thrips tabaci* Lin. and *Tetranychus telarius* L. appeared capable of transmitting TMV. Costa and Carvalho (1960) obtained negative results in a few tests with *Epitrex* spp. and

Trialeurodes vaporariorum (Westwood), but regularly obtained transmission with the mirid bug *Cyrtopeltis modestus* (Distant) during tests in which the controls remained healthy.

Hoggan's (1934) work was apparently done carefully and she found that aphids transmitted TMV from several hosts to tobacco. When over 300 *M. persicae*, *Aulacorthum solani* (Kltb.) and *Macrosiphum solanifolii* (Ashm.) were transferred to each of 50 tobacco plants from tomato, 24%, 78% and 60% respectively were infected. However, Valleau and Johnson (1937) concluded that insect transmission is of minor importance, if it occurs, and stated that Hoggan worked with unusual strains of TMV that were necrotic on pepper, whereas most strains cause only a mottle.

An ingenious method of finding out if aphids could imbibe TMV particles was used by van Soest and Cats (1956), who cut off the stylets of *M. persicae* feeding on an infected plant, collected the droplets emerging from the stylets and tested by inoculating tobacco, by a serological method and by examination under an electron microscope. No TMV was detected in them. Ossiannilsson (1958), on the contrary, found TMV-like particles in the gut of *A. solani*, *M. persicae* and a leafhopper fed on infected plants, but not in those fed on healthy ones, and suggested that aphids may acquire TMV occasionally when moving and probing, even if no particles emerged from cut stylets of aphids which had fed for a long time. Very few rods were visible in aphids, but they were numerous in *Eupteryx atropunctata* (Goeze).

Other sucking insects claimed to be vectors of TMV are mealy-bugs; *Pseudococcus citri* (*Planococcus citri* (Risso)) readily transmitted what was presumably TMV to tomato or tobacco (Olitsky, 1925; Newton, 1953). Gardner and Kendrick (1922), like Cleveland (1931), were convinced that insects were responsible for much virus spread among outdoor tomatoes because caged plants always remained healthy, and when flea beetles collected from infected weeds were released in a cage containing 338 tomato plants, 17 were infected, in contrast to none in a control cage with 218 plants. Other beetles (*Ootheca mutabilis* Sahlb.) transmitted the cowpea strain of TMV to cowpea and Bengal bean; batches of ten beetles, starved for 24 hours and given acquisition feeds of 24 hours, then transferred daily to healthy seedlings, ceased to be infective after one day (Chant, 1959).

Walters (1952) transferred TMV from tobacco to tobacco with the grasshopper *Melanoplus differentialis* (Thos.); after four to six hours' starvation and a five minutes' acquisition feed, about half the insects transmitted virus. Primary lesions usually occurred adjacent to feeding areas. After an acquisition feed of 20 to 30 minutes some fasting insects remained infective for 24 hours. Virus was detected in hopper faeces and their buccal fluid stayed infective for up to twelve hours. *Tettigonia viridissima* L. also transmitted TMV (Schmutterer, 1956); after short acquisition feeds of five seconds to five minutes single insects infected about half the plants tested. Infectivity declined sharply and was lost within ten minutes of feeding. This author also claimed transmission with *Mamestra brassicae* L. and *Agriolimax* sp. but gave no details. Caterpillars, of *Plusia gamma* L., infected six of 38 tobacco plants, but three of 280 controls became infected, so the result needs confirming (Sukhov and Vovk, 1945). The leaf-miner fly *Liriomyza langei* Frick. was also able to transmit TMV mechanically, presumably with its ovipositor, to some test plants but not to tomato (Costa, de Silva and Duffus, 1958).

Effects of TMV on growth

Virus strains and symptoms in tomato

Many serologically-related strains of TMV have been isolated from tomatoes. The "common mosaic" of tobacco crops (Johnson's tobacco virus 1) was often reported to be the virus

most common in tomato crops, causing ordinary or mild tomato mosaic (Allard, 1916; Ainsworth, 1933; Ainsworth, Berkeley and Caldwell, 1934). This causes a light and dark green mottle in tomato leaves, and sometimes some leaf distortion and slight plant stunting, but no necrosis. In winter the mottle is usually slight, but distortion more severe, often causing the extreme "fern-leaf" condition (Norton and Heuberger, 1933). This virus systemically invaded tobacco of the "White Burley" type, not causing local lesions, yet Smith (1960) recently stated that tomato mosaic virus commonly causes necrotic local lesions. McKay (1949) also implied that "common tomato mosaic" virus is uncommon in Irish tomato crops, which are usually infected with "single-virus streak" TMV, normally without showing any streak. That the common tobacco mosaic is different from the strain of TMV often found in tomato in Germany was shown by Melchers, Schramm, Trurnit and Friedrichfreksa (1940) and Uschdraweit (1952), for tomato mosaic caused only necrotic lesions on Java tobacco and *Nicotiana sylvestris* respectively, whereas tobacco mosaic did not, and invaded systemically, and symptoms caused by the two strains were different on several other test plants. Mixed infections of the two strains sometimes occurred in tomato. Perhaps the strain common in tomatoes has changed during recent years.

Two severe strains of TMV in tomatoes are "glasshouse streak", "stripe" or "tomato streak" or "single-virus streak", and yellow or "aucuba" mosaic. The streak virus causes a leaf mottle, and often distorted and, later, shrivelled leaves, necrotic brown stripes on the stem and petioles, and sunken irregular brown pits on the fruits; plants are usually stunted but often recover to give ordinary mosaic symptoms. The virus normally causes only necrotic local lesions on tobacco, but sometimes induces systemic necrosis. Ainsworth (1937) classified streak virus as a strain of Johnson's tobacco virus 1, and included also "enation mosaic" which causes severe malformation of tomato leaves and outgrowths on their undersides in summer. This virus also causes local lesions on tobacco, unlike tobacco virus 1.

Yellow mosaic causes a bright mottle on tomato leaves and fruit, some leaf distortion, and stunting which is more severe in winter. On tobacco the virus causes necrotic local lesions followed by bright yellow mottle, necrosis and distortion (Ainsworth, Berkeley and Caldwell, 1934).

Holmes (1941) described a strain of TMV that was common in *Plantago* spp. and which remained localised or occasionally systemically invaded tomato, causing chlorotic spotting and mottle; it was much less obvious than common TMV. However, in a later paper, Holmes (1950) stated that many strains of TMV occur in plantains and some appeared to be responsible for "internal browning" disease of tomato fruits; the virus spread rapidly in tomato crops, but not in plantains.

Potato virus X sometimes occurs with TMV to cause streak symptoms similar to those of "glasshouse streak", but this mixed streak was stated to be rare under glass in Britain (Jarrett, 1930; Ainsworth, 1933).

Allard (1916) recorded that symptoms occur ten to twelve days after cotyledon infection, but take 15—17 days to appear in plants several weeks old. Ainsworth (1933) found that young plants often showed symptoms in five days in summer, but took as long as three weeks in winter.

There is a sharp drop in transpiration rate coincident with the appearance of symptoms, but then the rate increases gradually, and usually TMV-infected leaves transpire faster than healthy ones (Heuberger and Norton, 1933a; Selman, 1945). The percentage water content of all plant parts is lower in infected plants during the early stages of the disease but later increases above that of healthy ones. During the incubation period before symptoms show, growth slows considerably (Ainsworth and Selman, 1936).

Age and vigour of tomato plants, and their environmental conditions, greatly affect symptom expression. Symptoms are often less severe as the plants age (Allard, 1916). Selman (1941) found that a mild and a severe strain of TMV from tomato, and the Rothamsted tobacco strain, all of which systemically infected tobacco, caused brown stem lesions early in some tomato plants but not in others; however, the plants recovered in two weeks. Both tomato viruses caused enations on a few leaves of tomato in early May after the first heavy watering, and Selman (1942, 1947) considered soil moisture to affect leaf symptom expression considerably. Similarly, Read (1934) found aucuba mosaic to be more severe in waterlogged than in well-drained soil. The number of infected plants might be affected as well, for increasing the amount of water supplied to tobacco and *Nicotiana glutinosa* plants before inoculating them with TMV greatly increased their susceptibility (Tinsley, 1953).

Symptom severity in young leaves, and TMV concentration, increased as the temperature was raised from 16 to 28°C., but after a maximum concentration of virus was reached, it decreased as host growth increased (Bancroft and Pound, 1956). Much can be done by experienced growers to alleviate the effects of infection. Because the sugars available for growth are less than in healthy plants, Harrison (1960) recommended growing infected ones at temperatures a few degrees lower than for healthy plants at night and at less than 80°F. by day. Free ventilation, frequent water sprays and adequate root moisture were also recommended to aid the growth of infected plants in bright weather.

The susceptibility of plants to infection is affected by other things than water, but experiments on the effects of nutrients have seldom been adequately done according to modern standards. Excess potash (Selman, 1943c) and optimum manganese (Rebowska, 1958) in relation to growth are reported to increase susceptibility. The latter author found that susceptibility was not affected by the source of nitrogen, organic or inorganic. More is known about the effects of nutrients on infected plants. Lack of potash, but not of any other major nutrient, greatly increased the incidence of necrotic streak, and addition of potash may cause affected plants to "grow out" of the necrotic stage (Ainsworth, 1932). Selman (1943c) found that development of symptoms in the variety 'Potentate' was retarded by additional lime or sulphate of potash. Selman (1947) suggested that much more could be done to induce resistance in crop plants by manurial and cultural treatments; these might affect tolerance, but it is doubtful if they would affect resistance to infection to an economic extent.

Movement of virus in the plant

This is not the place to discuss the physiology of infected plants, but the movement of the virus once it has entered the plant is of interest because of its influence on symptoms. When infection occurs through a leaf the virus multiplies therein for a few days and then moves into the phloem, whence it is carried first to the roots and then to the growing point, or to both simultaneously (Caldwell, 1931; Samuel, 1934; Kunkel, 1939; Capoor, 1949). This movement is rapid, and the isolated particles of virus by-pass many parts of the plant. The virus enters developing fruits at the same time as it travels through the stem, whereas adjacent leaves may remain uninfected for days or weeks; the more mature leaves are invaded successively from the top down until all are soon invaded in young plants, but large plants may never become completely invaded (Samuel, 1934). As the tomato plant grows by a succession of axillary meristems, which the fruit trusses terminate, it is not surprising that occasionally the lower trusses are infected before virus passes to the growing point (Selman, 1946). Selman suggested that localisation in the fruit may be more common than is realised and that virus may remain there unless growth and development are checked, thus causing food materials and virus to move from the fruit to other parts of the plant. By cutting newly-infected tomato plants into sec-

tions and rooting them, Kunkel (1939) showed that occasionally virus particles remain dormant for a long time in stem tissue and then multiply. There is no evidence to suggest that this occurs in whole plants, but when plants are infected through the roots virus may fail to invade the tops, especially when they are growing slowly (Fulton, 1941; Roberts, 1950).

Fruit yield and quality

Marketable yield of tomatoes can be affected in three ways by TMV: by (a) the number of fruit set, (b) the size of the fruit, and (c) the uniformity with which each fruit colours. Flavour and composition may also be affected, but little is known about this yet. In one analysis, infected fruits contained 31% less dry matter, 25% less sugar and 36% less vitamin C than healthy ones (Milinko, 1956), but in another the sugar content of healthy and infected fruits was similar, and infected ones had a higher vitamin C content (Rebowska, 1958).

(a) *Fruit set.* A decrease of 37% in numbers of fruit set in field-grown virus-infected tomatoes was reported by McCubbin (1918); losses of 42, 33 and 11% occurred when plants were infected 5, 20 and 54 days respectively after planting out (Heuberger and Moyer, 1931). Losses of 28, 36 and 3% occurred in one trial in Switzerland when field tomatoes were infected respectively at pricking out, on transplanting outside and six weeks later; in a second similar trial losses were 23 and 15% when plants were infected at pricking out or transplanting (Bovey *et al.*, 1957).

Comparisons under glass have proved difficult because the uninoculated plants have usually become infected inadvertently. Selman (1941) inoculated 'Potentate' tomatoes when the first flower trusses were opening, and compared them with uninoculated control plants which remained symptomless for nine weeks, until the fifth trusses were in bloom. The greatest difference in set was in the fourth truss, and the average percentage decreases in number of fruits were 21% when infected with a severe tomato strain of TMV and 17% when infected with a mild strain or the Rothamsted tobacco strain. In a similar experiment the following year, when once again the control plants remained uninfected for only twelve weeks, early infection with the severe strain caused a decrease of 13% of ripe fruit relative to late infection, the biggest decrease being in the second truss which was coming into flower when the symptoms were appearing.

(b) *Fruit yield.* Most estimates of the effect of TMV on yield have been made on tomatoes grown outside. In the U.S.A., Heuberger and Moyer (1931) found that the earlier the plants were infected the greater was the loss, from 57% when infection showed on 8th July, four weeks after planting, to 2% when infection first showed on 5th August. In plants inoculated on 26th June, five days after planting out, loss was 54%, falling to 11% when inoculated on 3rd September. This work was done on relatively few plants, from 10 to 40 in the different treatments. Alexander (1952) stated that loss differed with variety, time of infection and virus strain, varying from 52 to 31% when young plants were inoculated with the yellow strain, and from 30 to 15% with the green strain. Yields were depressed in three different varieties by 13, 3 and 12% in one year, and by 27, 21 and 13% the next year with a different strain of TMV (McRitchie and Alexander, 1957). Weber (1960) compared four varieties (two selected for TMV tolerance), infecting them nine days and one month after planting with the common tobacco strain, but another strain entered the trial and many of the control plants were infected. However, early inoculation decreased yield in the early and mid-harvest pickings, but in later pickings yields were less in late than in early-infected plants, or about the same. There was no significant loss in one of the "tolerant" varieties.

In New Zealand, Chamberlain (1934) obtained a 39% decrease in yield when plants were infected in the seedling stage with a mild strain of TMV. A severe strain decreased yield by 91% and no fruit was marketable. In Switzerland, Bovey, Canevascini and Mottier (1957) were able to keep control plants healthy in two out of three field trials; in these yield losses were 30 and 33% when infected at pricking out, 23% at transplanting outside, and 5% loss and a gain of 7% when infected six weeks later. Symptoms were most severe in plants inoculated at transplanting, those inoculated in the seedling stage having recovered, and those inoculated later never showing severe symptoms. Most of the loss was due to fewer fruits rather than smaller ones. In the following year loss was 30% when plants were infected in the 2–3 leaf stage, but as more fruits were unsaleable, the maximum loss of early saleable crop was 43%. There was a 5–6% gain of crop for every ten days delay in infection between the 30th and 100th day from sowing.

Less work has been done on the crop under glass. Heuberger and Norton (1933b) stated that the average loss from TMV under glass was 7% in well-grown plants, whereas Jones and Burnett (1935) found that ordinary TMV decreased yield by 15%, and streak virus by 44%, depending on the age of the plants when infected. Selman (1941) gave a much more detailed account of his experiments; in the variety 'Potentate', inoculated when the first truss flowers were opening, he obtained losses of 22% with a severe strain, 15% with a mild one and 20% with the Rothamsted tobacco strain of TMV, in comparison with plants kept healthy until the fifth truss was in bloom. The following year the severe strain caused a loss of 13% of ripe fruit in a similar experiment when the controls remained healthy until mid-season. There was a non-significant decrease in average fruit weight in both years, and most loss was due to fewer fruit.

(c) *Fruit quality.* The necrotic pitting caused by the "glasshouse streak" strain of TMV, the raised blisters caused by "mixed virus streak" and the yellow patches associated with the yellow or "aucuba" strain, have long been recognised, and many people have thought that different forms of "blotchy" or uneven ripening might be associated with ordinary mosaic virus infection. Ainsworth (1934b) found that only 25% of fruit from infected 'E.S.1' plants was marketable because of mottling after inoculation with the aucuba strain when the first truss was in bud, whereas 96% of fruit from healthy plants was saleable. Recently, however, an attempt has been made to rectify some of the confusion in the terms referring to ripening disorders (Cooper, 1958a), and work in the U.S.A. has attributed some forms of "internal browning" or "bronzing" to TMV. Presumably the tomato fruit can react in a few limited ways to internal disorders, and physiological, nutritional or pathological conditions may well stimulate similar reactions. Often "internal browning" symptoms are confined to the stem ends of fruits, most but not all fruits on a truss may be affected, and the symptoms may be limited to one or two trusses, earlier or later pickings being unaffected.

Perhaps the first suggestion that this condition might be induced by virus was made by Holmes (1941) who noted the association of some strains of TMV, particularly the ribgrass (plantain) strain, with "internal browning". Stoner and Hogan (1950), however, were unable to detect virus in several affected plants and attributed the disease to physiological factors. Canova (1954) attributed a similar disease in Italy to TMV, but Boyle (1956) was the first to establish that internal browning can be induced as a shock reaction after TMV invasion, affecting only fruits that are already set when the plant is infected. This accounts for the fact that plants infected before fruit sets are unaffected, as are fruits that develop after infection (Boyle and Wharton, 1957a, b). Nine isolates of TMV were used in the experiments and "internal browning" affected from 0 to 98% of fruit, according to the isolate, about three weeks after

infection. In a second trial 3 to 100% of fruits were affected. Very few fruits in uninoculated control plants showed the disorder and no other abnormal ripening occurred. In a later field experiment 21% of fruit were affected when plants were inoculated with one isolate, in contrast to 1% from uninoculated control plants which, however, were not tested for virus (Boyle, 1959). The internal browning usually was restricted to the fleshy parenchyma, and radiated from the stem ends, being most prominent near the shoulders and most severe between vascular bundles. The disease was particularly evident in unripe fruit; green and discoloured areas were usually not sharply demarcated, but the browning was sometimes visible through the epidermis (Whar-ton and Boyle, 1957).

TMV is not the only factor affecting the incidence of "internal browning", however, for some varieties of tomato are much more susceptible than others, and some conditions of light intensity and nutrition may induce a similar reaction in uninfected plants (Murakishi, 1959; Rich, 1958).

Virus inactivation

A few attempts have been made to decrease the susceptibility of tomato plants to TMV or to inactivate virus before it can infect them, whichever way the chemical used is assumed to act. Stoddard and Dimon (1949) watered tomatoes in sand culture with malachite green at 1/4000 in water on ten successive days and then inoculated them with TMV. One month later fewer plants were infected than in a control series, and those infected showed very slight symptoms. Howles (1957), however, found that neither malachite green nor 2-chlorophenoxyacetic acid affected susceptibility, although they delayed symptom appearance.

Fulton (1943) tested several substances as inactivators of viruses, including TMV, and among them was fresh cow's milk. This was followed up in England in 1953; unfortunately, no experiment was done, but all the plants in one house were sprayed with milk diluted nine times with water, every ten days, with the result that only 5% of the plants were obviously infected instead of the expected 95% (Newell, 1954). This was widely publicized, but in other places plants sprayed and handled only by workers with their hands wet with milk solution were as readily infected as unsprayed controls (Harrison, 1957; Crowley, 1958), although the latter author showed that such a solution partially inhibited virus and decreased the number of lesions on *N. glutinosa*, even when sprayed on the plants seven days before inoculating them. Perhaps such treatment merits further attention, for Hare and Lucas (1959) found that 10% of tomatoes 4—8 in. high became infected when sprayed and allowed to dry before being inoculated with TMV-infected tomato sap, and 60% when sprayed just after inoculation, in contrast to 90% of the unsprayed inoculated plants. When they tested the inhibitory effect of the protein components of bovine milk and blood, none was as effective as reconstituted skim or homogenized milk at the concentrations used (Lucas and Hare, 1959). Earlier, Lucas and Winstead (1958) tested the antibiotic Cytovirin by atomizing it over young tomato plants and one hour later inoculating one leaf of each with TMV. All the control plants showed symptoms within 14 days but 70% of treated plants showed no mosaic 30 days later. Wittmann (1958) showed that this chemical could profoundly influence the symptom incubation period, but completely inhibited virus multiplication only at a concentration near the toxic level. Both Cytovirin and thiouracil affect growth as well as virus production (Bergmann, 1958), so are unlikely to be of practical value, especially as Cytovirin is known to be highly toxic to man. In experiments on virus spread with infected and healthy tomato plants growing in close contact, watering the soil or spraying the plants with several chemicals that were systemically distributed failed to prevent or significantly delay spread (Howles, 1959).

Thus attempts to prevent virus spread or cure infected plants have not been very successful, and it might be more profitable for growers in the immediate future if more work were done on the use of chemicals applied through the roots or leaves to ameliorate the effects of the virus on infected plants. Bhatt and Verna (1958) reported that field-grown tomatoes usually died in India when suffering from mixed virus streak, whereas infected plants sprayed with solutions of β -3-indolylpropionic acid or α -naphthalene acetic acid recovered.

Conclusion

Despite all the work that has been done on tomato mosaic, several aspects of its epidemiology are still in dispute and many widely-accepted ideas are based upon inadequate data. TMV is perhaps the virus most easily transmitted from plant to plant by touch, and yet it is obvious that many workers have not taken adequate precautions to prevent contamination.

The epidemiology of a disease must be studied so that efforts at controlling it can be based on a full understanding of how it spreads. We do not have this for TMV at present, so more work is needed to clarify the following questions:

As TMV is seed-borne in or on the testas of tomato seeds, but not in the embryos, how do seedlings become contaminated?

Can the concentration of virus on seeds be decreased to such an extent that seedlings will not be contaminated from the testas?

If seedlings are infected from the testas do symptoms show early enough for infected plants to be destroyed before transplanting?

What is the relative importance of the different sources of TMV—seed, soil, structures, clothing, tools, tobacco, weeds—in initiating the disease in Britain?

How long will the virus persist in soil, on clothing, etc.?

Do present methods of soil sterilisation eliminate TMV, and what can be done to eliminate the other sources?

Can anything be done to prevent or decrease spread once TMV has entered a crop?

To what extent do insects, birds and other animals, in addition to man, spread TMV in glasshouses?

Can there be prolonged latent periods following infection?

What are the effects of different strains of TMV on the yield and quality of different tomato varieties, and what can be done culturally to overcome losses?

Some day plant breeders may produce commercially useful tomato varieties that will resist or tolerate virus. That day seems still far off, so answers to the above questions are being sought at the Glasshouse Crops Research Institute in the hope that they will help to minimise losses from tomato mosaic.

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4. ELECTRICAL CONDUCTIVITY OF THE CASING LAYER IN RELATION TO FRUITING OF THE CULTIVATED MUSHROOM

by

P. B. FLEGG

It was shown previously (1) that adding soluble salts to the casing layer had highly significant effects on fruiting. The appearance of pinheads was delayed, and the numbers and total weight of mushrooms was reduced, but the average weight of the mushrooms was increased. Further experiments have provided evidence that the effects on fruiting are related to the electrical conductivity of the casing layer irrespective of the salt used.

Experimental methods

The experiments, P.13 and P.16, were carried out in 8 in. plant pots, and the procedure, methods of analysis and crop recording were essentially as described in the Annual Report for 1956.

In experiment P.13 four salts—sodium, calcium and magnesium chlorides and sodium sulphate—were added to the casing soil immediately after casing, each at two levels, namely, 100 and 200 milli-equivalents per pot. These, together with a control, made a total of nine treatments, and the experiment was laid out as a 9×9 Latin square.

Experiment P.16 involved the use of one salt only, calcium chloride, which was applied to the casing layer immediately after casing at six levels, 0, 7.5, 15, 22.5, 30 and 37.5 g. per pot. The six treatments were laid out in eight randomised blocks. Throughout these experiments the moisture content of the casing layer was kept within the same range on all pots.

Results

Experiment P.13 was designed to obtain further information on the relation between quantity or type of salt and its effect on fruiting. The cropping results at eight weeks are given in Table I, and the effect on numbers of sporophores is shown graphically in Figure 1. From these it is seen that sodium chloride had the greatest effect on the start of fruiting, numbers of sporophores and yield, and sodium sulphate the least, with magnesium and calcium chlorides having an intermediate effect. When the effect of the four salts, each at two levels, on numbers of sporophores is considered in terms of their influence on the electrical conductivity of the soil directly after treatment (Figure 2) and at the end of cropping (Figure 3), a linear relation is apparent. The highly significant correlation coefficients are shown on the graphs.

TABLE I
EXPERIMENT P.13
EFFECT ON FRUITING OF THE ADDITION TO THE CASING
LAYER OF FOUR SALTS, EACH AT TWO LEVELS

	Additions of salt (<i>milli-equivalents per pot</i>)								S.E. of means	
	Control	Sodium sulphate		Magnesium chloride		Calcium chloride		Sodium chloride		
		100	200	100	200	100	200	100		200
Days, casing to first pinheads	19.3	19.9	20.7	23.3*	21.9	21.0	28.3**	25.2**	38.0**	± 1.86
Weight, g. per pot at 8 weeks	214.0	209.0	179.4*	170.8**	146.7**	170.6**	115.7**	148.1**	64.8**	± 13.6
Number of mushrooms per pot at 8 weeks	30.9	27.0	16.4**	21.0**	13.6**	17.3**	8.8**	14.3**	4.9**	± 1.52
Average weight (g.) per mushroom at 8 weeks	6.9	7.8	10.8	8.3	10.9	9.9	13.1	10.4	13.2	
Electrical conductivity of soil after treatment (<i>millimhos</i>)	0.6	3.1	5.9	3.9	7.5	4.6	8.8	4.0	7.3	

* Significantly different from control at $P < 0.05$.

** " " " " " " $P < 0.01$.

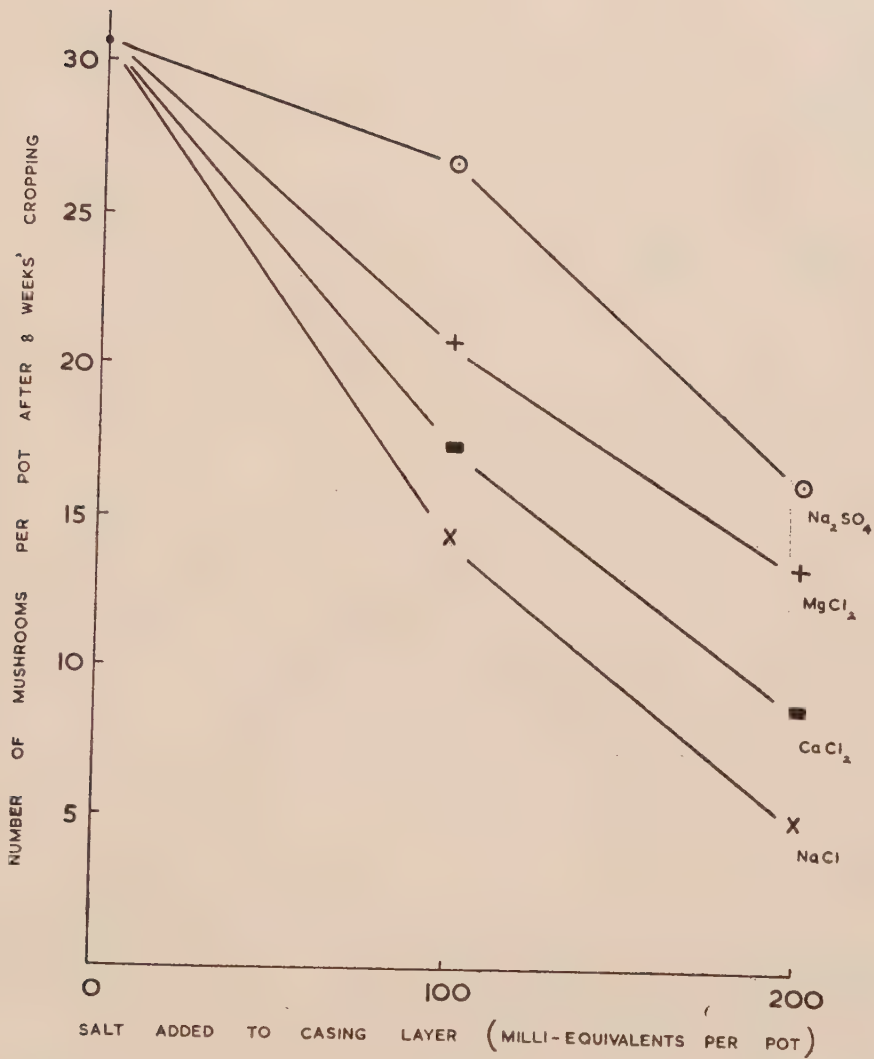


FIGURE 1. Experiment P.13. Effect on fruiting of four salts each added at two levels to the casing layer.

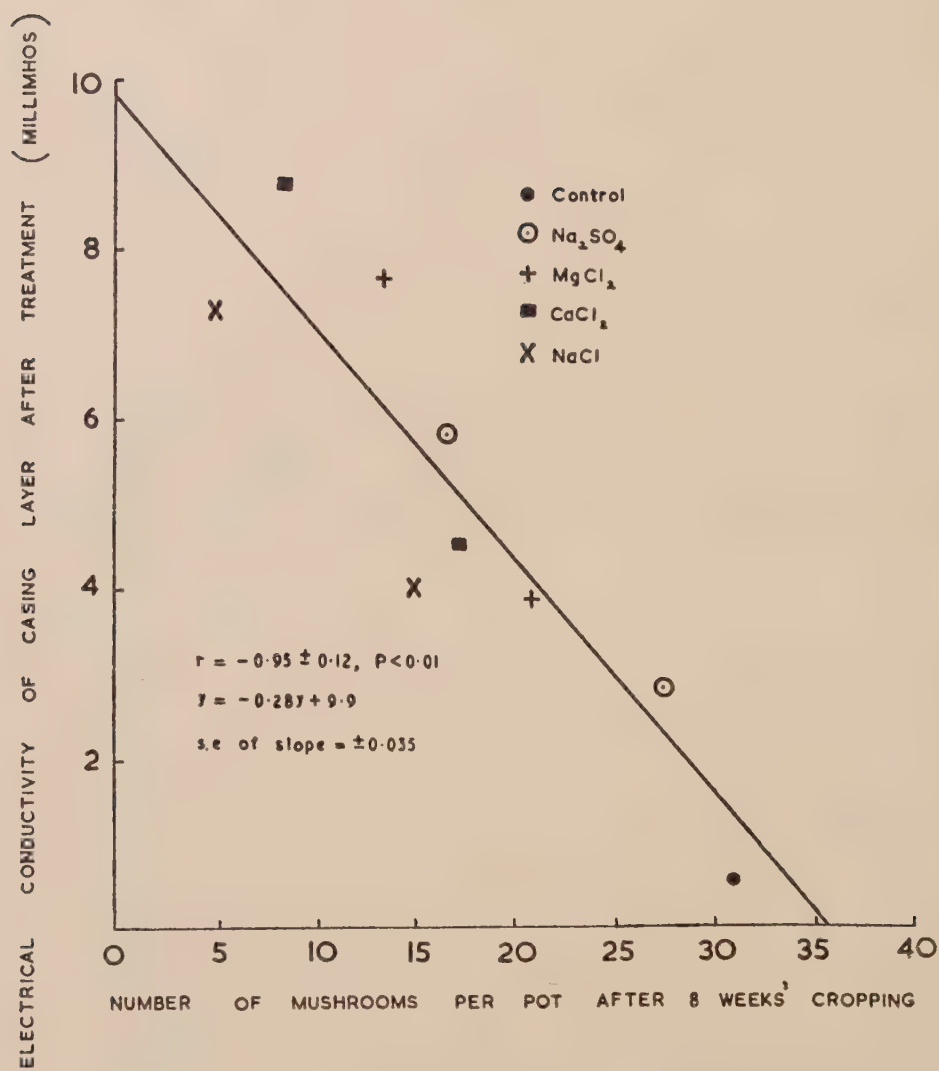


FIGURE 2. Experiment P.13. Relation between fruiting and electrical conductivity of the casing layer after treatment.

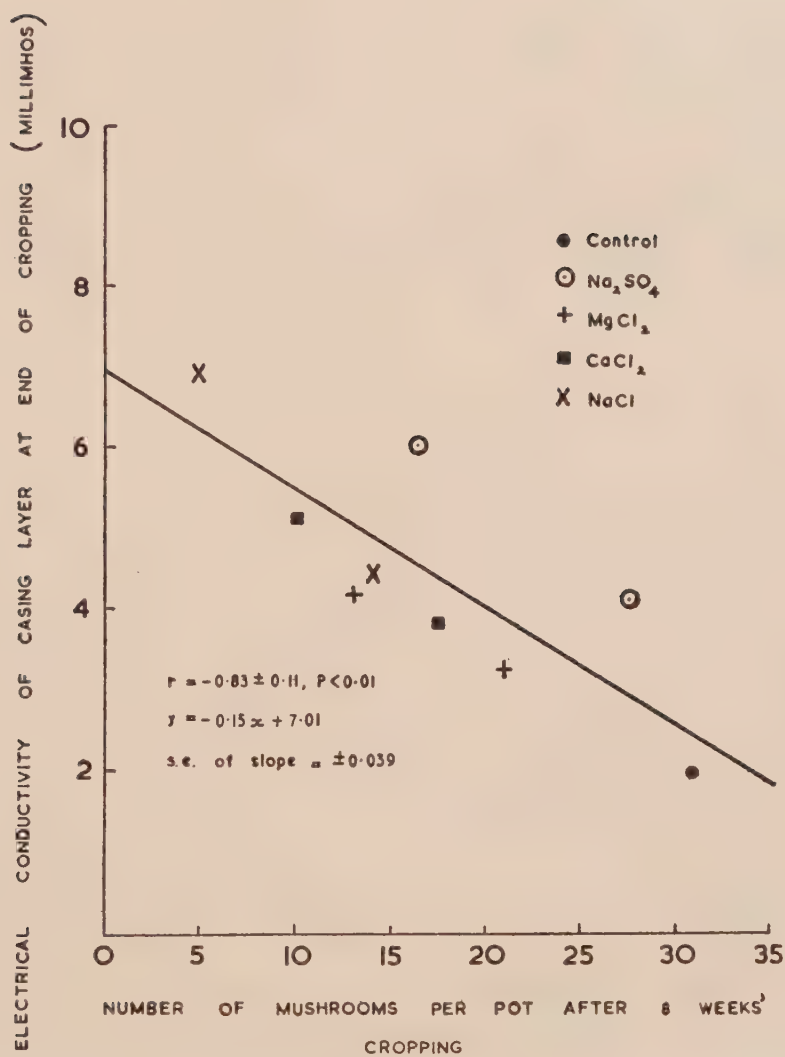


FIGURE 3. Experiment P.13. Relation between fruiting and electrical conductivity of the casing layer at end of cropping.

This relation is confirmed by data (1) from an earlier experiment, P.1, in which three salts at three levels in factorial combination were tested. The data from this experiment have been replotted in Figure 4 to show numbers of sporophores in relation to electrical conductivity of the casing soil immediately after treatment.

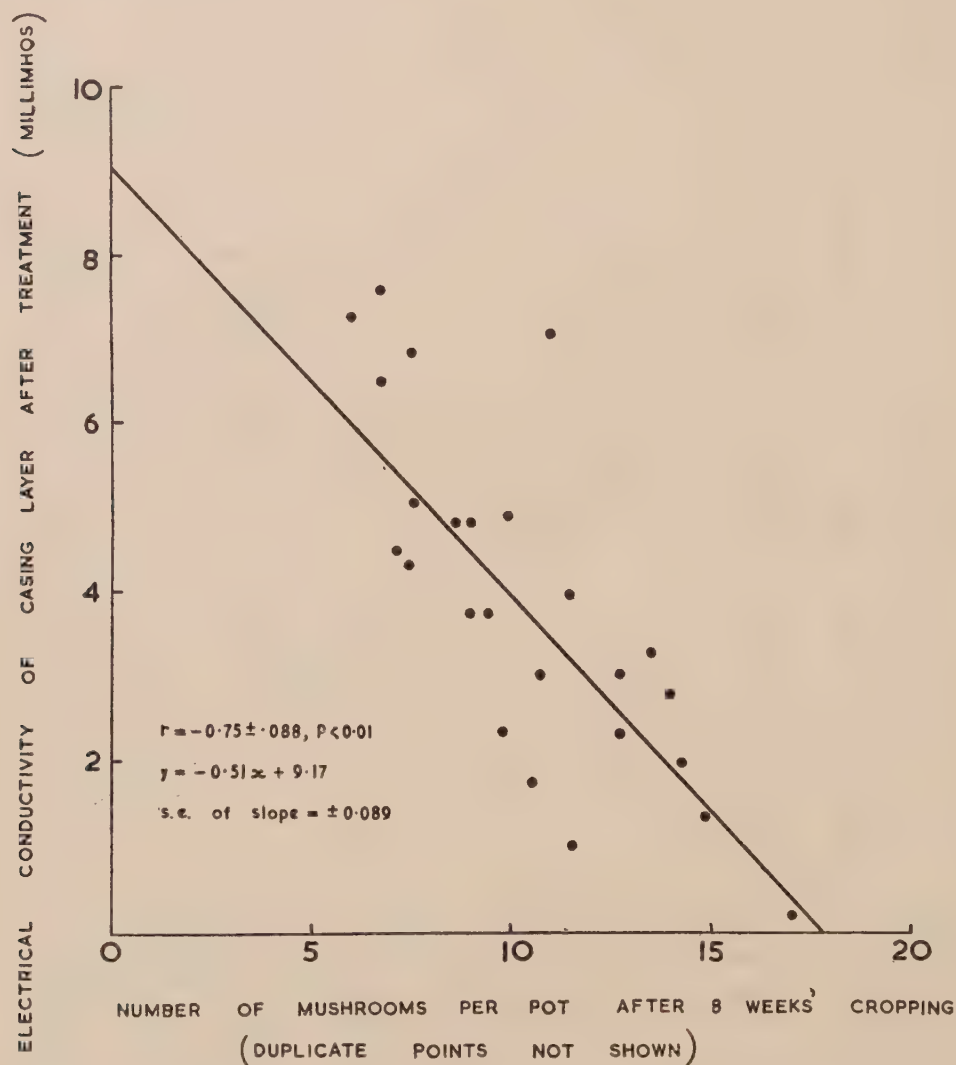


FIGURE 4. Experiment P.1. The relation between electrical conductivity of the casing layer and fruiting.

Similarly, the effect on the start of fruiting is also related to the electrical conductivity of the casing soil after treatment. The correlation coefficient between the electrical conductivity of the casing soil after treatment and the number of days from casing to the appearance of the first pinheads was 0.74 ± 0.2 ($P < 0.01$) in experiment P.13 and 0.74 ± 0.08 ($P < 0.01$) in experiment P.1.

Thus from these two experiments a relation between fruiting phenomena and electrical conductivity of the casing layer is evident.

The regression lines shown in Figures 2 and 4, if extrapolated to a point at which no sporophores are formed, indicate that the electrical conductivity of the soil at the time of casing would be about 9 to 10 millimhos (pC 2.0—1.9). Experiment P.16 was designed to obtain further information on the inhibition of fruiting at high salt concentrations, the results being shown in Table II. Increasing quantities of calcium chloride both delayed and reduced fruiting until there was no fruiting at all, within the fourteen week period after casing, where the electrical conductivity of the casing soil was initially 16.4 millimhos. Between 7 and 13 millimhos fruiting was very poor, only three out of eight pots producing pinheads where the initial conductivity was 7.45 millimhos. These results provide quite good agreement with the values predicted from Figures 2 and 4 at which fruiting would be inhibited. Precise data on this point are difficult to obtain for, as shown previously (2), if high levels of salt are added the concentration in the casing layer tends to drop as the experiment proceeds, and fruiting may eventually occur on some pots when the salt concentration has reached a sufficiently low level. Furthermore, although there must be a point at which fruiting and growth is impossible, inhibition of fruiting may be confused with excessive delay in the start of fruiting.

TABLE II
EXPERIMENT P.16
EFFECT ON FRUITING OF CALCIUM CHLORIDE
ADDED TO THE CASING SOIL

	Weight of calcium chloride (g. per pot)					
	0	7.5	15.0	22.5	30.0	37.5
Number of pots fruiting (out of 8)	8	8	3	3	2	0
Days, casing to first pinheads	16.25	27.0	60.0	80.6	82.0	—
Number of mushrooms per pot	10.3	5.4	1.3	3.0	1.5	0
Electrical conductivity of soil after treatment (millimhos)	0.36	4.92	7.45	9.10	12.70	16.40
pC of soil after treatment	3.45	2.31	2.13	2.04	1.92	1.79

Discussion

From the results of experiments P.1 and P.13 it is evident that none of the salts had any marked specific action, and their effect on the fruiting of the mushroom is a common property of each salt. The effect of soluble salts is correlated with the electrical conductivity of the treated casing soil, a factor which is closely related to the osmotic pressure of the soil solution. It is possible to infer, therefore, that there is a relation between the moisture stress in the casing layer and fruiting of the mushroom.

It has also been shown that there is a point at which fruiting is completely inhibited, and that this point is reached at electrical conductivity values within the approximate range of 9–16 millimhos (soil : water ratio 2.5 : 1). It is interesting to note that these values are very similar to those obtained for normal composts (2), and the high salinity of the compost may be one reason why sporophores do not normally develop on it without a casing layer.

The relation between moisture stress in the casing layer and fruiting has been discussed elsewhere (3), but before it can be accepted unreservedly, data relating fruiting and actual measurements of moisture stress are required. Apparatus for this purpose is being developed.

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5. MUSHROOM COMPOSTS AND COMPOSTING:

A REVIEW OF THE LITERATURE

by

P. B. FLEGG

The results of research on mushroom composts have been reviewed previously by Lambert (24) and Stoller (45) in papers which covered the whole field of mushroom cultivation. In this review particular attention is paid to the nutrition of the cultivated mushroom and the composting process, in order to determine where further study is required.

Traditionally, horse manure and wheat straw are the basic ingredients of mushroom composts, and although a number of substitutes have been tried during the past thirty years they are still widely used. Mushroom mycelium will grow in unfermented horse manure, but satisfactory development is prevented by heating up of the manure and competition from other organisms. It is therefore necessary to compost the manure in order to produce a medium which will no longer heat up, and in which the quantity of readily available nutrients for competing organisms is considerably reduced. The preparation of a compost suitable for mushroom growing is still very much dependent on the skill and experience of the grower. A well-prepared compost is essential for a successful crop, for subsequent cultural operations cannot produce a good crop from a compost of poor quality. Research on both the fundamental and practical aspects of mushroom composts is therefore extremely important to the industry.

Nutritional aspects

The nutrients required by micro-organisms involved in the fermentation must be considered as well as those subsequently required by the mushroom. Adding nutrients to the compost may benefit the mushroom either directly or by favouring the growth of micro-organisms necessary for satisfactory composting.

It has not yet been possible to produce mushroom sporophores on synthetic media of known composition, and all information on the nutrition of the mushroom obtained with such media relates to the vegetative stage of growth only (38). The nutritional requirements for fruiting may be quite different from those for vegetative growth. The most important and comprehensive work on the nutrition of mushroom mycelium in liquid culture is that of Treschow (47), who has critically reviewed the previous work on this subject. He worked mainly with a brown strain, but where comparisons were possible he found no differences between a brown and a white strain. Bohus (4), using a similar method, found considerable differences in the ability of some twenty brown strains to utilise certain nutrients. He also found that the ability to utilise some substances was influenced by the other nutrients in the medium. The white strains, which are widely grown in Great Britain and the United States of America, have not been studied in detail, although some workers, for instance Humfeld and Sugihara (22), have investigated the possibility of growing mushroom mycelium for flavouring soups in liquid culture, but the strains which grew well under these conditions were not suited to growing in compost. Information derived from liquid culture experiments is of limited value to a study of mushroom composts. There are differences between strains and it is difficult to relate results obtained in simple liquid media to the complex conditions in composts; also the data relate only to vegetative growth.

Carbon

Treschow (47) and Bohus (4) have shown that, in liquid media, a wide variety of carbon compounds can be used by the mushroom mycelium. Many mono-, di- and poly-saccharides were readily utilised, particularly those which are decomposition products of cellulose and the hemicelluloses (e.g., D-xylose, D-glucose and cellobiose). From these results both concluded that cellulose and the hemicelluloses in the compost are of primary importance to the mushroom. In this they disagreed with Waksman and his co-workers (51, 52, 53) who, from studies of the changes in the composition of the compost during cropping, concluded that the mushroom derived most of its nutrients from lignin and proteins, and that the hemicelluloses and cellulose were utilised to a lesser extent. In support of his conclusions Treschow quotes the work of Kliushnikova *et al.* (23), who found that hemicelluloses were utilised and lignin was not, and Cayley (10), who found that the mushroom mycelium attacked cellulose and the hemicelluloses during its early stages of growth, and lignin only later. Treschow also points out that if lignin were the most important source of carbon, it would be better to ensure a high proportion of lignin in the compost by prolonged composting. Sinden (39, 41), however, has shown that lengthening the period of composting adversely affects yields. In Great Britain and other countries growers are tending to compost for as short a time as possible (19). It is important that this point be investigated more fully for it has a direct bearing on composting practice, and a sound basis for preparing mushroom composts cannot be found while the best sources of carbon for the mushroom are in doubt.

Other sources of carbon found to be utilised include apple pectin and the salts of certain organic acids, for example sodium pyruvate and calcium oxalate. Burrows (5, 6) has shown that oxalate, present in mushroom beds during cropping, is re-assimilated under certain ill-defined conditions, though not necessarily by the mushroom mycelium.

In describing their method of composting, Sinden and Hauser (42) refer to unpublished evidence that the mushroom is one of the few micro-organisms able to utilise compounds resulting from the caramelisation of carbohydrates.

Nitrogen

Ammonium salts of organic and inorganic acids are good sources of nitrogen for the vegetative growth of mushroom mycelium, and some complex ammonium salts, such as ferric ammonium citrate and magnesium ammonium phosphate, are particularly good (47). Bohus (4) however, found that some strains of mycelium tolerated higher concentrations of the ammonium ion than others. Treschow (47), Casimir and Heinemann (11) and Bohus (4) have independently found that, in liquid culture, many amino acids be utilised; among the best were asparagine, and alanine and glycine (glycocol). Bohus also found that urea was at least as good a source of nitrogen as glycine. Waksman and his co-workers (51, 52, 53) found that proteins and water-soluble organic nitrogen complexes accumulate during the composting process, and there is general agreement that proteins and amino acids are the main sources of nitrogen for the mushroom. Ammonium salts which may be present in the compost are also utilised, but nitrogen supplied as nitrate is not a good source (47).

The importance of nitrogen compounds in the compost has long been realised, and a considerable amount of experimental work has been carried out on this aspect. Lambert and Ayers (26) found that yields were significantly increased when horse manure was supplemented with substances rich in protein such as cotton seed meal and brewers' grains. Each pound of

nitrogen added in this form to a ton of manure produced an increase in yield of 20—30 lb. of mushrooms. In Great Britain supplementing racing stable manure with nitrogen-rich materials is common practice (19).

The development of synthetic composts emphasised the need to study the optimum level of nitrogen required and the best supplement to use. Sinden (42) recommended, for his system of short-composting, about 1.5% nitrogen at stacking on a dry matter basis, whereas in Edwards' (15, 16) formula, based on dried blood and wheat straw, the level of nitrogen recommended is 2%. More information is needed on the optimum level of nitrogen required in a mushroom compost. The effect of different sources of nitrogen on the fermentation process and the best time at which to add them also require further study.

Minerals

In liquid culture, Treschow (47) found that calcium, potassium and magnesium are required for optimum mycelial growth, and that calcium was particularly important. Phosphorus was also necessary, the optimum concentration being about 0.0066 M.

Pizer (30) and Pizer and Thompson (32) found that adding calcium sulphate (gypsum) to the compost had a beneficial effect on the growth of the mycelium, but interpreted their results in terms of the physical condition of the compost; this is discussed later. Edwards (15, 16) in his formula for a synthetic compost, included calcium carbonate as well as gypsum.

Most of the successful formulae for synthetic composts include supplements of potassium and phosphorus. In 1943 Stoller (43) concluded that previous attempts to prepare a satisfactory synthetic compost had failed because the requirement for potassium had been neglected. He found that yields were doubled when a compost, based on spent licorice roots and brewers' grains, was supplemented with potassium salts. Sinden (40) also obtained increased yields from adding potassium chloride, but not inorganic phosphate or bone meal, to his synthetic composts. Edwards (14, 15, 16, 17) found that superphosphate added to synthetic composts at the end of composting had beneficial effects on yield and the start of cropping, but not when it was added at the beginning. Although he included potassium chloride in his list of activators to be added at the start of composting (15, 16) he found subsequently (18) that omitting it had no adverse effect on cropping. Working with horse manure, Lambert and Ayers (26) found no effect on yield when either potassium or phosphorus were added. In all experiments of this type the results must depend on the quantity of each element already present in the manure or other ingredients. Willam-Engels, Trzcinski and Willam (58) found that straw and manure normally contain enough potassium for satisfactory growth of the mushroom mycelium but, if potassium was lacking, it was better added as sulphate than chloride. Calcium, phosphorus and potassium supplements are probably of greater importance in synthetic composts than in horse manure, and further work on the optimum levels of each is required.

Trace elements and growth substances

A careful study of the requirement of trace elements by the mushroom has never been reported, but in a limited study Treschow (47) found that iron was essential, at least in the vegetative stage. In his opinion, earlier work by Bechmann (2), who found that zinc and iron were required, was unreliable.

Stoller (44, 45) has suggested nine elements as likely to be required by the mushroom, and reports that a mixture of these added to straw-based composts usually produced a significantly

beneficial result. Edwards (14) also found that a similar mixture of trace elements produced an earlier and increased yield.

In studies in which he used a synthetic nutrient solution Treščow (47) found that neither a brown nor a white strain of the mushroom would grow without the addition of growth substances. Of the pure substances which he tried biotin and aneurin were effective, but sodium pantothenate, nicotinamide and meso-inositol were not. He also found that adding a vitamin B preparation, aneurin or biotin, to composted horse manure resulted in higher yields. When beef extract was added to a prepared straw compost Edwards (14) found that the number and weight of mushrooms was increased. Lambert and Ayers (26), however, could find no effect on yield when mixtures of vitamins, including the B group, were added to horse manure composts. Adding thiamin to the compost before spawning was found by Hoffman (21) to increase yield. He also found that the increase so obtained was greater when the yield of the untreated beds was relatively low than when they yielded well. It is of course to be expected that the response to trace elements and growth substances added to the compost will depend on the amounts of each already present.

The addition of trace elements or growth substances to the prepared compost results in increased yields under some circumstances. Little progress in this field can be expected until more definite information is available on the trace elements and growth substances required by the mushroom and the compost microflora, and the conditions under which composts are likely to be deficient in them.

Chemical and microbiological changes

Early work on the decomposition of farmyard manure and similar materials was handicapped by the lack of reliable methods of analysis. A further difficulty arises from the need to allow for loss of bulk from relatively large stacks during composting.

Our knowledge of the changes occurring in mushroom composts owes much to the work of Waksman and his colleagues (51, 52, 55, 56, 57). They found that the hemicellulose and cellulose fractions were decomposed with equal rapidity during composting and that lignin, being relatively resistant to decomposition, accumulated. At the same time microbial activity resulted in the synthesis of protein and a reduction of the amount of free ammonia and soluble nitrogen compounds. Similar changes have been found by Sinden and Hauser (41). These workers have also described a process of caramellisation of carbohydrates which occurs in composts made by their method (42).

In a very limited study, on one stack, Trzcinski and Casimir (49) isolated a number of amino-acids from the compost. Some, for example aspartic acid and asparagine, disappeared in the course of composting, while the concentration of others, glycine and serine, increased slightly.

Burrows (7, 8), in his study of the chemistry of mushroom composts, reviewed much of the previous literature and described methods of analysis and the use of acid-insoluble ash determinations in calculating losses of dry matter during composting. He pointed out that conservation of nitrogen in mushroom composts was important because yields depended partly on a high level of nitrogen in the compost (Edwards (14)). His work showed that losses of nitrogen from the compost depended on the initial nitrogen content or carbon : nitrogen ratio, the temperature in the stack and the initial rate of conversion of the nitrogen source to ammonia. A low carbon : nitrogen ratio and consequently high nitrogen content was essential to obtain high yields. Burrows (7, 8) found that losses of nitrogen could be kept to a minimum

by composting at 55–60°C., or by using nitrogen sources which are not too rapidly converted to ammonia.

Losses of dry matter during the composting and peak-heating process were also studied by Burrows (5, 6) and Burrows and Flegg (9). The nitrogen : calcium ratio was found to affect the total dry matter loss, and high yields were associated with large losses of dry matter during composting. These results, however, may be of limited application for they were obtained mainly from composts which were not peak-heated. Peak-heating tended to remove any differences between composts in the loss of dry matter during composting.

The thermophilic decomposition of plant residues has been studied by Waksman and his co-workers (55, 56, 57), who found that decomposition took place most rapidly at 50°C. At this temperature thermophilic fungi and actinomycetes were very active, but at higher temperatures the fungi were less in evidence and at lower temperatures there was a delay before the active micro-organisms became established. It was also found that calcium carbonate was essential for rapid decomposition to take place, especially of cellulose by the thermophilic fungi. Blondeau (3) has recently made a study of the thermophilic actinomycetes, *Streptomyces* sp. and *Micromonospora* sp., which develop in the compost between 55–60°C., particularly during peak-heating.

La Touche (29), in an attempt to discover whether the apparent superiority of horse manure as a material for mushroom composts was due to a characteristic flora, isolated a number of organisms, some of which were hitherto unknown. Although the work was not completed, no evidence of any important differences in the flora of horse manure and synthetic composts was obtained by the time the work ceased.

The more conspicuous “weed” fungi found in mushroom composts have been listed by Lambert (24), and it has been found that such conditions as excessive moisture and a high pH favour some of these fungi at the expense of the mushroom. Those groups of micro-organisms which are considered important during the cropping period have been given by Stoller (45).

Although the decomposition of plant and animal residues has been studied in some detail (50) much of the work is not directly applicable to mushroom composts.

Physical and environmental factors

Temperature, aeration and water content

In an early study of the distribution of oxygen and carbon dioxide in mushroom compost stacks, Lambert and Davis (28) found four main areas in which different conditions existed. The conditions within these areas arose largely from the effect of aeration, or lack of it, on microbial activity. At the base of the stack they found an acid anaerobic core in which the carbon dioxide concentration was at its highest and the temperature at its lowest (37–55°C.). The hottest areas (65–80°C.) were about 2–4 ft. in from the sides of the stack and about 2–3 ft. below the surface; in these areas decomposition was most rapid and the compost was neutral or alkaline. The outer layer, exposed to the air, had the highest oxygen content, but was generally cool (45°C.), with very little decomposition taking place. The remainder of the stack was aerobic and between 45–60°C. A more uniform distribution of oxygen, produced by placing ventilating tiles under the stack, reduced the anaerobic core and caused a wider distribution of the high temperature areas. In a later study Lambert (25) found that compost produced at temperatures between 50–60°C. was the most suitable for mushroom growing, providing conditions had favoured aerobic fermentation. The anaerobic core and the hottest areas produced unsuitable compost, but if subsequently subjected to aerobic fermentation at

50—60°C. it was then rendered suitable. Thus Lambert concluded that peak heating, during which the compost is kept at 50—60°C. under aerobic conditions, must be an integral part of the composting process.

The stacks investigated by Lambert were 12 ft. or more wide and about 4 ft. high. In order to avoid having an anaerobic core the width of stacks has been much reduced, and some growers use a system of ventilation at the base of the stacks. Sinden and Hauser (42) were able to produce an almost homogeneous compost, with only traces of the zoning described by Lambert, by using stacks of similar shape but smaller in width. These workers laid great stress on the importance of the size, shape and compactness of the stack, having found that stacks could be made larger with loose and long material than with dense substances, and that the stacks should be smaller in summer than in winter.

It is interesting to note that the optimum temperature range for composting found by Lambert (50—60°C.) agrees well with the temperature for maximum decomposition (50°C.) found by Waksman *et al.* (55, 56, 57), and with that at which nitrogen losses are at a minimum (55—60°C.) (7, 8). The method of short-composting devised by Sinden and Hauser (41, 42), however, is reported to produce temperatures of over 75°C. throughout most of the stack, but the latter part of the process consists of maintaining the compost at a temperature of 52—60°C. under aerobic conditions for up to three days.

The water content of the compost is acknowledged to be important, but has not been the subject of much work. Lambert and Ayers (27) have shown that yields were considerably reduced when the moisture content of the compost was below 60%, while Sinden and Hauser (42) have recommended that the water content should be about 70% at the start of composting. Flegg (20) has suggested that the salinity of the compost may be important, and that this may affect the moisture stress in the compost. Related to salinity and moisture content is the degree of dispersion of the various constituents of the compost. Pizer (30) and Pizer and Thompson (32) found that when the colloids in the compost were dispersed, growth of mushroom mycelium was poor. The addition of calcium sulphate to flocculate the colloids enabled a strong growth of mycelium to be obtained. A number of flocculating substances were tested, and calcium sulphate was found to be the most satisfactory. As a result of this work, adding calcium sulphate (gypsum) to mushroom composts to prevent "greasiness" is now a common practice among growers. According to Pizer and Thompson the addition of calcium sulphate gives the compost a more granular structure, and the ability to hold water is increased. As a result, aeration and drainage are improved, and it is possible to add considerably more water without the compost becoming too wet.

pH

Both a white and a brown strain of the cultivated mushroom were found by Treschow (47) to grow best in liquid culture or compost at *pH* 6·8—6·9. Pizer (31), who points out the difficulties of measuring the *pH* of composts, found that a good growth of mycelium was obtained in composts between *pH* 6·2 and 8·5, and concluded that the mushroom mycelium will tolerate a wide range of *pH* values. Measurements during composting have shown that the *pH* tends to rise to a maximum and then falls, finishing between 6·4 and 7·6 (5). The highest *pH* values were obtained from composts containing the highest level of nitrogen. Superphosphate has been found to lower the *pH* of composts (5, 31).

Practical and economic aspects

The supplementation of horse manure and synthetic composts has already been discussed under nutritional aspects, but its economic aspects urgently require investigation.

The considerable amount of work done on developing synthetic composts was stimulated mainly by shortages and the high cost of horse manure. Among the most notable formulae are those of Waksman and Reneger (54), Demolon, Burgerin and Marcel (13), Stoller (43), Sinden (39,40), Edwards (15, 16), and Yoder and Sinden (59). Many of these synthetic composts have proved successful and are in use commercially, but there is still a need for means of reducing their cost before they are likely to be used more widely.

Much useful work on the practical aspects of composting has been done by Rasmussen (33,34), who has also developed a satisfactory method of composting pig manure (35). Other materials which have been used for composting, with some success, include sawdust (37), peat (1) and penicillin waste (12).

The production of mushroom compost is expensive in terms of materials and labour, and the industry is quick to take up new techniques offering economies in both. Mechanisation has brought about much saving of labour in composting. Although used only for research, the unconventional continuously rotating drums for preparing compost described by Stoller, Smith and Brown (46) and Trocmé and Sarazin (48), are of interest and perhaps give a hint of future developments. Economy of materials is claimed for the short-composting method developed by Sinden and Hauser (41, 42). This process results in a satisfactory compost and is becoming increasingly popular among growers.

Conclusions

It is clear that further research on all of the major aspects of the compost and composting is required. The greatest bar to progress is our ignorance of the nutritional requirements of the mushroom for fruiting. A method of growing the mushroom to fruition in a medium physically similar to compost, yet of known composition, would be of considerable value. If the nutritional requirements for growth and fruiting of the mushroom were known, it would be possible to define more clearly the aims to be pursued during the preparation of the compost; the study of the chemical and microbiological changes occurring in the compost could be carried out with a clearer purpose. Meanwhile, our knowledge of the chemistry and microflora of the compost is limited, and more careful and detailed study of these aspects is also required.

The physical conditions in the compost are no less important, and more work on the water content in relation to the fermentation processes and yield of mushrooms is particularly needed.

There are many practical problems connected with composting still to be solved, and a solution of some of them would no doubt be easier if the whole process were more fully understood. At present a rather empirical approach has to be adopted, but this can still help considerably towards solving some of the more immediate problems, such as the most economic supplementation of horse manure and a cheaper synthetic compost.

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APPENDIX

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- FLEGG, P. B., GANDY, D. G. and HUSSEY, N. W. Bulletin No. 34, "Mushrooms".
- SHEARD, G. F. Bulletin No. 22, "Soil Sterilisation".
- SHEARD, G. F. Bulletin No. 115, "Construction and Heating of Commercial Glasshouses".

APPENDIX

METEOROLOGICAL RECORDS, 1960

(Agricultural-Meteorological Station: Glasshouse Crops Research Institute, Worthing Road, Rustington, Littlehampton, Sussex)

	Air temperature (mean screen, °F.)		Rainfall (inches)	Sunshine* (mean daily hours)	Soil temperature (mean at 0900 hr. G.M.T., °F.)				Wind † (mean daily miles run)
	Max.	Min.			4 in.	8 in.	2 ft.	4 ft.	
January	44.5	34.3	2.70	1.57	39.3	40.7	42.2	— a	— a
February	45.8	34.4	3.30	3.04	38.4	39.5	42.1	43.1	163
March	48.9	39.6	2.04	2.57	43.3	43.8	45.4	44.4	143
April	55.7	40.7	0.69	5.12	47.8	47.7	48.7	46.8	167
May	61.8	46.2	1.69	5.75	56.4	54.8	54.3	50.7	104
June	67.1	48.8	1.60	7.97	62.5	61.1	60.2	55.7	148
July	65.7	51.5	3.20	5.04	61.1	60.7	61.2	58.0	195
August	66.2	53.4	5.93	5.75	60.8	60.6	61.8	58.6	105 b
September	63.5	50.1	5.37	4.32	56.8	57.3	60.2	58.3	121 c
October	57.9	47.1	6.95	3.16	51.6	52.2	55.4	55.0	157
November	53.2	40.8	5.96	2.58	46.4	46.9	50.4	51.0	206
December	45.5	34.5	4.21	1.55	40.2	41.5	45.4	46.9	148
Total or mean	56.3	43.5	43.64	4.03	50.4	50.6	52.3	51.7	151

* recorded by Campbell-Stokes instrument

† recorded at height of 6 ft. 6 in. above ground level

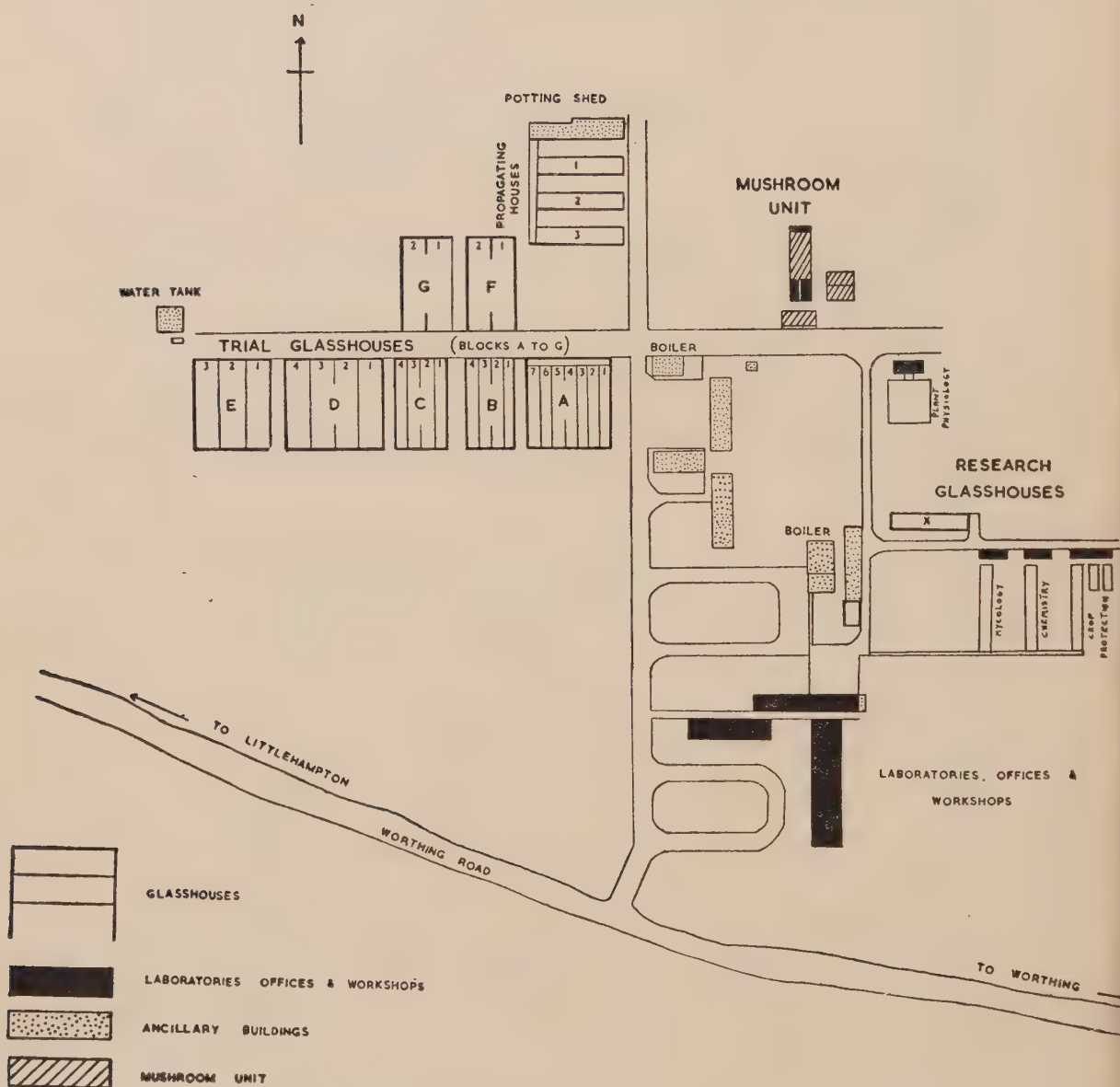
a not available

b based on 11 days' observations

c based on 28 days' observations

A. C. BUNT

GLASSHOUSE CROPS RESEARCH INSTITUTE



Layout of the glasshouses, laboratories, and other buildings

THE JOURNAL OF HORTICULTURAL SCIENCE

THE JOURNAL OF HORTICULTURAL SCIENCE, which is sponsored by the Long Ashton Research Station and the East Malling Research Station, welcomes contributions on horticultural science from research workers at home and abroad. Papers for publication and all communications should be sent to the Editors at East Malling Research Station, Maidstone, Kent.

Papers in the current Volume 36 (1961) and already accepted towards the next come from the sponsor stations, the Glasshouse Crops Research Institute, the Scottish Horticultural Research Institute, the John Innes Institute, the National Vegetable Research Station, Manchester University and Wye College, and from Canada, New Zealand and Ghana.

Of particular interest to growers of glasshouse crops are physiological studies of the growth of leaves and of flowering in tomatoes, and experiments on the liquid feeding of that crop; two papers relating to the accumulation and addition of soluble salts to the casing layer of mushroom beds; and the reduction of saprophytic contaminants in the carnation "cultured-cutting" test.

Fruit crops reported on are apple, plum, raspberry, strawberry and cocoa; there is a first report on rootstocks for roses; and there are papers on the nutrition of outdoor vegetables and the soil for John Innes composts.

Among the subjects discussed are flower initiation, storage, shade and manuring for cocoa, root anatomy, plant breeding, manuring for seed production, frost resistance, fruit tree viruses and the apple spray programme, and rootstocks for plums.

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